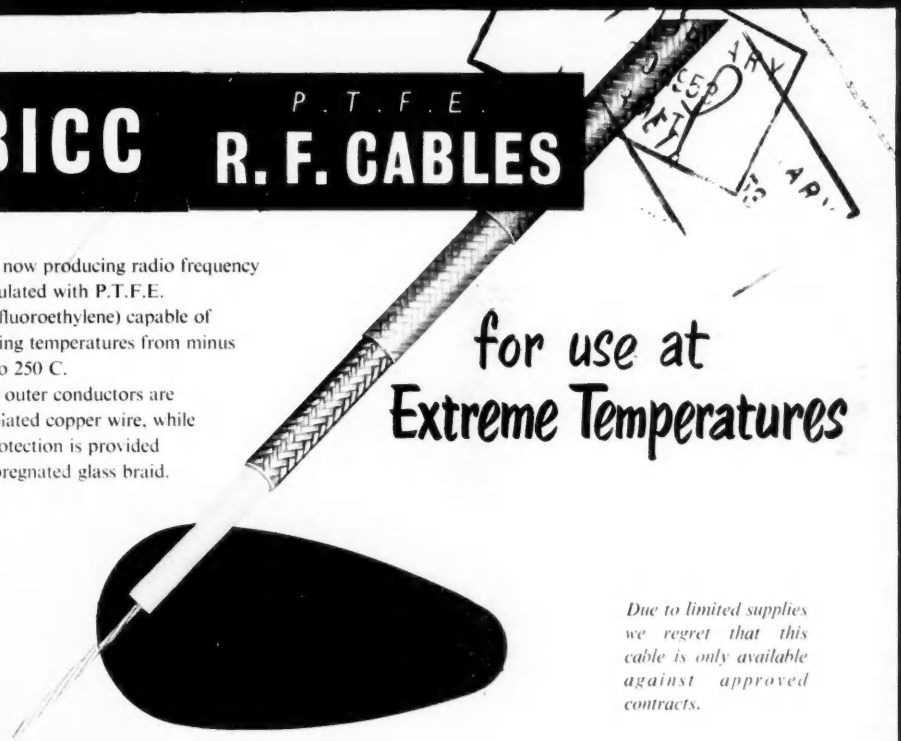
Electronic Engineering

BICC P.T.F.E. **R.F. CABLES**

BICC are now producing radio frequency cables insulated with P.T.F.E. (polytetrafluoroethylene) capable of withstanding temperatures from minus 75 C up to 250 C.
Inner and outer conductors are of silver-plated copper wire, while overall protection is provided by an impregnated glass braid.



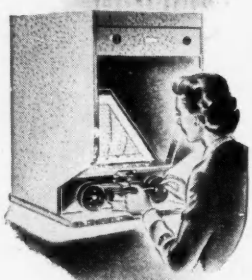
for use at **Extreme Temperatures**

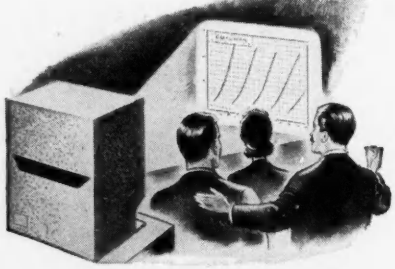
Due to limited supplies we regret that this cable is only available against approved contracts.

BI Callender's

BRITISH INSULATED CALLENDER'S CABLES LIMITED
21, BLOOMSBURY STREET, LONDON, W.C.1

Taking the large view....





The Ediswan Microfilm Reader provides the simplest means of viewing 16mm or 35mm Standard British, American or Continental film in spool or strip form. The screen is clearly readable in a normally lighted room without screening, the optical arrangements being designed to give maximum contrast with hard focussing over the whole screen. The Reader is extremely simple to operate; self contained, quiet and cool in operation it does not interfere with other workers. A simple mirror attachment converts it to a Projector for viewing by small audiences. Full details are given in Publication R.1544. May we send you a copy?

EDISWAN

Microfilm Reader

Radio Division

THE EDISON SWAN ELECTRIC CO. LTD., 155 Charing Cross Road, London, W.C.2

Tel.: Gerrard 8660 • Grams: Ediswan, Westcent, London • *Member of the A.E.I. Group of Companies*

MR102

X

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is: Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to: "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY, R.N. Scientific Service. The Civil Service Commissioners invite applications from electronic engineers or physicists for three permanent posts in Gloucestershire as Principal Scientific Officer to take charge of teams responsible for design of large scale equipment and its development to prototype stage. Age at least 31 on 31st December, 1952. Candidates must possess a first or second class Honours Degree or be corporate members of the Institution of Civil or Mechanical or Electrical Engineers, or produce evidence of outstanding ability. Research experience essential. One post requiring ability to lead a team in design and development of radio receivers and ancillary equipment for use at frequencies above 30 megacycles. Two posts require knowledge of high speed electronic switching and data storage and handling. Both digital and analogue techniques are relevant. Inclusive London salary £1,075-£1,459 (men); £949-£1,280 (women). Somewhat less in provinces. Starting salary exceptionally above minimum according to qualifications and experience. Particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S4226/53. Application forms to be returned by 20th August, 1953. W 2577

ADMIRALTY, Royal Naval Scientific Service. Engineers and Physicists (particularly with electronics) required for appointments in (a) Senior Scientific Officer and Scientific Officer grades (Ref. A246/52A), and (b) Experimental Officer and Assistant Experimental Officer grades (Ref. A247/52A) in Experimental Establishments in London, Portsmouth, Weymouth areas and Scotland. Candidates, British subjects, for (a) must possess first or second class Honours Degree in Physics or Engineering, or high professional attainments such as corporate membership of appropriate professional institution with suitable experience and responsibility and for (b) should possess one of following qualifications: University Degree in Science, Engineering or Mathematics, Graduate membership of appropriate professional institution, Higher National Certificate, Final Certificate of five-year grouped course in relevant subject at City and Guilds of London Institute or comparable institution, Higher School Certificate with Mathematics, or Science as principal subject or equivalent qualification. S.S.O.s at least 26 years of age with at least three years' approved experience, London salary (men) £812-£1,022 per annum; S.O.s at least 21 years £440-£707; E.O.s at least 26 years £681-£838; A.E.O.s at least 17½ years £274-£607. Rates for women and posts in provinces somewhat lower. Starting salaries above minima may be granted according to age and experience. All appointments unestablished (with F.S.S.U. for S.S.O. and S.O.) but some opportunities to compete for established posts. Application forms from M.L.N.S., Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1 quoting appropriate reference. W 2578

BBC requires qualified radio engineer (engineering Degree preferred) as Standards Engineer in Equipment Department based S.W. London. Duties: to assist in standardization of electrical components and mechanical parts in broadcasting equipment; liaison with departments concerned with design, production, supply; maintaining record of standard components and parts. Qualifications: considerable experience of design and production sound and television studio control room equipment and manufacture of Services equipment, intimate and wide knowledge of products of manufacturers of electrical components. Salary £795 (higher if qualifications exceptional) with annual increments to £1,065. Detailed applications to E.E.O., B.B.C., London, W.1, quoting ref. E.798. W 2549

B.B.C. requires Technical Assistants for career in Operations and Maintenance Department, sound and television broadcasting. Knowledge mathematics, electricity, magnetism to G.C.E. Ordinary Level; experience electrical/radio engineering advantage. Preferred age 20-25; older if experienced. Must be willing to serve anywhere in U.K. Starting salary £360 with annual increments and excellent prospects of promotion to Engineer grade with good technical training facilities. Possibility promotion after 2 years. Apply briefly stating: (1) Reference "T.A.11", (2) Full Name, (3) Address, (4) Nationality, (5) Age, (6) Details of National Service or exemption (if under 26) (7) Qualifications, (8) Relevant experience to E.E.O., B.B.C., London, W.1. W 2552

B.B.C. requires engineer for research into microphones, loudspeakers, and other audio-frequency developments. Degree or equivalent electrical engineering/physics essential. Knowledge electrical communication, music. Based Kingswood, Surrey. Starting salary £590 (higher if qualifications exceptional) rising by annual increments to £800 max. Applications to Engineering Establishment Officer, B.B.C., London, W.1, within 7 days. W 2590

DEPARTMENT OF SCIENTIFIC & INDUSTRIAL RESEARCH require Experimental Officer at Food Investigation Torry Research Station, Aberdeen, to work on general physical problems relating to fish. H.N.C. or better in physics. Research experience, including electronics experience, desirable. Minimum age 26, preferably under 31; salary in the range £650-£800 (men). £555-£676 (women). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A116/52/A. Closing date 14th August, 1953. W 2576

ELECTRICAL ENGINEERING DEPT., Imperial College, London, S.W.7. Lectureship in Vacuum Electronics. Applications are invited for a Lectureship in vacuum electronics tenable in the Department of Electrical Engineering. The Lecturer will be co-responsible for running a Post-Graduate Course in Applied Electron Physics, with laboratory exercises comprising the physics and technology of modern vacuum electronic devices. Thorough knowledge of electron physics necessary, industrial experience desirable, but not essential. Salary in the scale £600—£50—£900: —£50—£1,150, according to experience. Applications to the Professor of Electrical Engineering. W 2557

ELECTRICAL ENGINEERS and Physicists required by Ministry of Supply, Farnborough, Hants., for theoretical and experimental research on design and performance of new weapons and associated guidance and control systems; instrumentation of flight trials and analysis of trials data. Qualifications: 1st or 2nd class Honours Degree or equivalent in Physics or Elec. Eng., with interest in electronics, servo mechanism theory or analogue computing. Salaries within range, Scientific Officer, £417-£675. Women somewhat less. Posts unestablished. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A168/53/A. W 2551

ELECTRICAL OR MECHANICAL ENGINEER required by Ministry of Supply Design Establishment near Sevenoaks, Kent, to lead section engaged in design and development of electrical and mechanical components and of complete control schemes for armament equipments. Qualifications: 1st or 2nd class Honours Degree or equivalent in Elec. or Mech. Eng. and at least 3 years' post graduate research experience. Some practical knowledge of electronics desirable and experience of one or more of following required: electrical machines and control gear design; servo mechanisms; hydraulics and I.C. engines. Salary within range: Senior Scientific Officer (min. age 26), £781-£980. Women somewhat less. Post unestablished. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical & Scientific Register (K), 26 King Street, London, S.W.1, quoting D285/53A. Closing date 15th August, 1953. W 2591

GOVERNMENT OF CEYLON. Applications are invited under the Technical Co-operation Scheme of the Colombo Plan for the post of Expert Technician in the installation, maintenance, repair and operation of electro-cardiographic and electro-encephalographic apparatus. Duties include training of personnel. Six months' appointment. Applicants should be aged 30-45 years. Salary at the rate of £1,000 per annum, plus overseas allowance at the rate of £670 per annum for a married man or £265 for a single man, together with allowance of Rs.35 per diem, payable by the Ceylon Government towards the cost of board and lodging, and outfit allowance. First-class return passage. Free medical treatment and duty travel allowance in Ceylon are also provided. Write giving full particulars of experience and qualifications and the names of two referees to the Secretary, Ministry of Health, Division 5A, Savile Row, London, W.1. W 2592

PROFESSIONAL ENGINEERS in various Government Departments. The Civil Service Commissioners invite applications for about 80 pensionable posts in a wide variety of mechanical and electrical engineering duties. Applications may be accepted up to 30th September, 1953, but an earlier closing date may be announced. Candidates must be under 35 on 1st January, 1953, with extension for regular service in H.M. Forces and up to two years for permanent Civil Service. For the Post Office they must be at least 21, for the Ministry of Supply and Ministry of Civil Aviation at least 23, and for all other Departments at least 25 on that date. Generally a candidate must possess a University Degree in Engineering or be a Corporate Member of one of the professional institutions—Mechanical Engineers, Electrical Engineers, or Civil Engineers or have passes in, or exemption from, Sections A and B of the corresponding Associate Membership examinations. Exceptionally, candidates of high professional attainment, but without the specified qualifications, may be admitted. For some posts Associate Fellowship of the Royal Aeronautical Society or an Honours Degree in Physics will be accepted. Inclusive salary scale (men in London) £628 (at age 25) to £970. Starting salary according to age up to £875 at 34. Candidates entering below age 25 will start at salaries varying from £429 at age 21 to £549 at age 24. Prospects of promotion. Salaries of next higher grades are £970-£1,280 and £1,331-£1,536. Somewhat lower for women and in the provinces. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S85/53. W 2583

TECHNICAL ASSISTANTS Grade III. Vacancies exist in Scotland and Northern Ireland for technical assistants to work on electro-mechanical computers and servo mechanisms. Initial salary is in the range of £396 to £533 a year depending upon age and location, rising by annual increments to a maximum of £612 a year. Applicants should have experience of this type of equipment, and preferably have technical qualifications equivalent to Ordinary National Certificate. Knowledge and experience of electronic valve circuits is essential. Applications to ADME, HQ 3 AA Group, Riccarton House, Currie, Midlothian. W 2575

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 *inclusive or a woman aged* 18-59 *inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order,* 1952.

ADDITIONAL SENIOR AND JUNIOR ENGINEERS are required by a small but progressive firm of electronic instrument manufacturers in Surrey for interesting development work on important projects. Applicants should possess a Degree in physics, and should have industrial experience and a practical mind. Both salary and prospects will be good for the right men. Apply Box No. W 2539.

AN ELECTRONIC ENGINEER is required for the development of prototype spectrometric equipment. An interest in research is desirable. Salary, in the range £550-£750 per annum, according to qualifications and experience. Box No. W 2582.

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

AN ENGINEER is required for the layout and development, to the prototype production state, of electronic equipment of a new type. Applicants, who must be British born, should preferably have had experience of work of this kind in the radio, radar or communications field, and should have a Degree or suitable alternative training and experience. The post will carry a starting salary in accordance with age and experience. Write giving full details of qualifications, etc., to Personnel Officer, Ericsson Telephones Ltd., Beeston, Notts. W 2547

APPLICATIONS ARE INVITED for the undernoted vacancies: Electronics Development Engineer with University Degree or equivalent qualifications, also practical experience in design and development work. Technical and Laboratory Assistant with Higher National Certificate in Electrical Engineering or City and Guilds Telecommunication Certificate. Preference given to person with practical knowledge of radar and laboratory work. Electronics Engineer with knowledge and practical experience in micro-waves, electro-mechanical measurements and servo-mechanisms. Applications by letter giving details of education, qualifications and experience to The Secretary, Messrs. Barr and Stroud Limited, Anniesland, Glasgow, W.3. W 2503

BELLING & LEE LTD., Cambridge Arterial Road, Enfield, Middlesex, require research assistants in connexion with work on electronic components, fuses, interference suppressors and television aerials. Applicants must be graduates of the I.E.E. or possess equivalent qualifications together with similar laboratory experience. Salary will be commensurate with previous experience; five day week, contributory pension scheme. Applications must be detailed and concise, and will be treated as confidential. W 138

BELLING & LEE LTD. wish to appoint a working chief for their type-test laboratories. These are fully equipped for testing electronic components to R.I.C. and R.C.S.C. Specifications, and the applicant must have had experience in this field. This is a permanent position with wide scope for the right man. Salary will be in accordance with experience and qualifications details of which will be treated confidentially: contributory pension scheme. Secretary, Cambridge Arterial Road, Enfield, Middlesex. W 171

CHEMIST OR PHYSICAL CHEMIST required for interesting research and development work on problems associated with vacuum tubes and semi conductors. Applicants should have a good Honours Degree and preferably, but not essentially, with previous experience in this field. Salary according to age and experience. Excellent conditions of employment. 5 day week. Contributory Pension Scheme. Apply Personnel Officer, Mullard Research Laboratories, Cross Oak Lane, Salfords, Near Redhill, Surrey. W 2564

DECCA RADAR LIMITED requires a senior engineer to take charge of the testing of high-power centimetric radar equipment. Previous experience of high-power radar, including receivers and A.F.C. systems, is required. A good salary, commensurate with experience, will be offered to the right man, for whom there are excellent prospects in this progressive and expanding company. Please apply giving full details of experience and stating salary required to Ref. F.L., Decca Radar Limited, 1-3, Brixton Road, London, S.W.9. W 176

DECCA RADAR LIMITED invites applications from young graduate scientists and engineers with good Honours Degrees. The posts offer first-class careers with excellent prospects in radar engineering. British Nationality essential. Apply, Ref. CPH/1, Decca Radar Limited, Research Laboratories, 2, Tolworth Rise, Surbiton, Surrey. W 173

DECCA RADAR LIMITED invites applications from young engineers who are interested in radar as a career and who have taken or are engaged in taking their H.N.C. The posts available offer opportunities for undertaking intensive development work over a wide field of radar, microwave link, and associated techniques. The chances of rapid advancement are good for men of ability. British Nationality essential. Suitable candidates with no radar experience may be accepted for training. Apply, Ref. CPH/A, Decca Radar Ltd., Research Laboratories, 2, Tolworth Rise, Surbiton, Surrey. W 174

DECCA RADAR LIMITED invite applications from experienced microwave engineers to join the Company in its extensive work in a wide field of microwave link and radar development. The Company offers excellent starting salaries and first rate opportunities for men to exploit their initiative and to rise rapidly to responsible posts. Graduates without industrial experience who are prepared to undertake intensive training are also invited to apply for junior posts. Applicants must be of British nationality. Apply in writing, quoting ref. MW, to Research Director, Radar Laboratory, 2, Tolworth Rise, Surbiton, Surrey. W 177

DEPUTY CHIEF MECHANICAL INSPECTOR required by world-famous manufacturer of Radio and Radar equipments in the Home Counties. This is a responsible appointment and applications can only be considered from first-class men of good education and technical qualifications, possessing a sound knowledge of light engineering as applied to the manufacture of electronic equipment. Familiarity with machine shop practice, tools and jigs is essential and applicants must be capable of controlling a large A.I.D. approved Inspection Organization. This appointment is permanent and pensionable with good prospects. Applications, which will be treated in confidence, quoting ref. IAA, should be addressed to Box No. W 2593.

DESIGNER required by electrical component manufacturers in N.W. London. Applicants must possess some knowledge of radio frequency circuits, pulse forming networks design, and preferably have experience in the electronic, radio and television industry. Superannuation scheme. Write stating age, full details of experience and salary required to Box No. W 2555.

DESIGNER / DRAUGHTSMAN required by The English Electric Co. Ltd., Luton. Must be fully experienced in radar or electronic equipment and conversant with RCS 1000 Standards. Good mechanical and circuit knowledge is essential. This is a responsible and progressive position leading a small team of draughtsmen. Salary around £700 with housing assistance for suitable married candidate. Applications to Dept. C.P.S., 336, Strand, W.C.2, quoting ref. 1119. W 2469

DESIGNER DRAUGHTSMAN required to take charge of department responsible for mechanical design of interesting miniature electronic work. Excellent porspects. Apply Box No. W 1800.

DESIGNER DRAUGHTSMAN (RESEARCH) required. Varied work involving drawing analysing performance and developing precision apparatus from engineers' sketches. Opportunity to rise to status of development engineer for man with proven ingenuity and sound critical faculty. Apply in writing giving age, previous experience and salary required to Personnel Department, Kelvin & Hughes Ltd., New North Road, Barkingside, Essex. W 2594

DESIGNER DRAUGHTSMEN with experience of electronic apparatus. Salary in excess of A.E.S.D. rates to suitable applicants. Write giving details of experience and qualifications to: Chief Draughtsman, Pye Limited, Colneside Works, Trout Road, West Drayton, Middlesex. W 2565

DEVELOPMENT ENGINEER, aged 24/35 required by organization in Lancashire for laboratory work in connexion with Quartz and Synthetic Crystal design and manufacture. Applicants should have a Degree in Physics or Electrical Engineering, or Higher National Certificate, or equivalent. Previous industrial experience and knowledge of High Frequency Radio Circuit technique will also be an advantage. The post available is permanent, with contributory Pension Fund and full staff status. Applicants are invited to write giving full details of qualifications, age and experience to Box No. 248, Dorland Advertising Limited, 18/20, Regent Street, London. S.W.1. W 2559

DEVELOPMENT ENGINEERS with either radio or communication engineering Degrees and some practical experience are required for work on oscillographs and associated amplifiers at our new Research Laboratories. Applicants should have good mathematical ability. Write giving full details of qualifications and experience, stating range of salary required to Southern Instruments Limited, Oscillograph Division, Camberley, Surrey. W 1788

DEVELOPMENT ENGINEERS. Marconi's Wireless Telegraph Co. Ltd., Chelmsford, have vacancies in their Aeronautical Development Group for qualified engineers with experience enabling them to make an immediate useful contribution to the work of the group, which includes research into and development of airborne communication and navigational aid equipment, Applications (which will be treated as confidential) are invited especially from engineers having design experience of communication receivers, mobile transmitters or small electro-mechanical devices. The positions offered to suitable applicants, who will be responsible for the particular phase of work on which they are engaged. In certain cases houses may be available. Please write giving full details and quoting ref. 875C, to Dept., C.P.S., 336/7, Strand, London, W.C.2. W 2569

DEVELOPMENT ENGINEER, aged 24/35 required by organization in Lancashire for laboratory work in connexion with Quartz and Synthetic Crystal design and manufacture. Applicants should have a Degree in Physics or Electrical Engineering, or Higher National Certificate, or equivalent. Previous industrial experience and knowledge of High Frequency Radio Circuit technique will also be an advantage. The post available is permanent, with contributory Pension Fund, and full staff status. Applicants are invited to write giving full details of their qualifications, age and experience to Box No. 214, Dorland Advertising Ltd., 18/20, Regent Street, S.W.1. W 2521

DEVELOPMENT ENGINEER required by E.M.I. Engineering Development Limited. Applicants must have sound basic training in electronics with experience in design of equipment incorporating servo mechanisms. The post carries a good starting salary and prospects. Apply in writing with full details to Personnel Dept. (ED/124), E.M.I. Eng. Dev. Ltd., Hayes, Middlesex. W 2580

DRAUGHTSMEN, Senior and Junior, required. Design and Layout experience of Electronic and Electro-mechanical equipment and/or mechanical computors essential. Facilities exist for further technical training under the supervision of E.M.I. Institutes Ltd. Apply by letter stating age, nationality and experience to E.M.I. Engineering Development Limited, Wells Division, Penleigh Works, Wells, Somerset. W 2462

DRAUGHTSMEN experience in Radio and Television Receiver Design (and small mechanical details) able to prepare drawings for manufacturer of prototype equipment. Apply in writing to Employment Manager, Ferguson Radio Corporation, Great Cambridge Road, Enfield, Middlesex. W 2548

E. K. COLE LTD., Electronics Division, Malmesbury, Wiltshire, require Draughtsmen (Mechanical or Electrical of National Certificate Standard), aged 21 to 25 years, for interesting and varied work on Radar and Communication Equipments: also for Test Gear. Excellent conditions and prospects. Apply in writing to Personnel Manager. W 2458

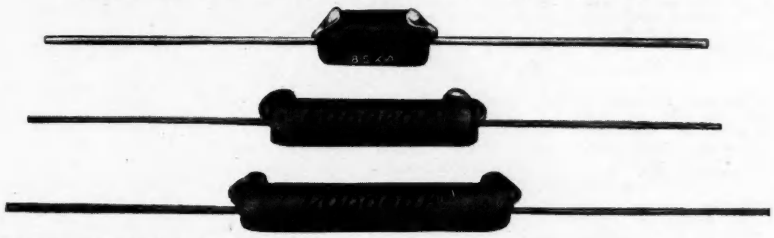
ELECTRONICS ENGINEER. Physics Degree or equal, wanted by light engineering company in Yorkshire to inaugurate and develop industrial electronic devices and instruments. Share in company offered in return for high technical ability and experience. Spare time basis to start if necessary. No objections resident London area. Full particulars in confidence to Box No. W 1798.

ELECTRONIC ENGINEERS required by The General Electric Co. Ltd., Brown's Lane, Allesley, Coventry, in their Development Laboratories, for work on: (a) Trials Team in connexion with Guided Weapons; 2 Senior Engineers also 3 Engineers. (b) Servo-Mechanisms; 2 Engineers. (c) Magnetic Amplifiers; 1 Engineer. (d) Pulse Circuitry; 4 Engineers. (e) Microwave Circuits; 1 Senior Engineer, 2 Engineers. (f) Test Equipment; 1 Senior Engineer, 3 Engineers. (g) General Radar Circuit Development; 1 Senior Engineer, 3 Engineers. Applicants, preferably with a Degree or an equivalent qualification should have had at least two years' experience in the development and engineering of Service equipment as well as experience in one of the above. Houses on the outskirts of Coventry, near our

CLASSIFIED ANNOUNCEMENTS
continued on page 4

VITREOUS ENAMELLED WIRE WOUND RESISTORS

LWV4-K and LWV4-L R.C.S.C. Type Approved.



The following sizes are at present being manufactured :

Type	Commercial Rating (watts)	Equivalent Services Rating (watts)	Nominal Diameter	Nominal Body length
LWV4-I	3	—	6 m.m.	16 m.m.
LWV4-J	4	3	6 m.m.	21 m.m.
LWV4-K	6	4.5	6 m.m.	34 m.m.
LWV4-L	10	6	6 m.m.	45 m.m.

ACCURATE ● STABLE ● RELIABLE ● ROBUST

Please write for our illustrated leaflet No. E.E./LWV.

Labgear (Cambridge) Ltd.

WILLOW PLACE, CAMBRIDGE, ENGLAND. *PHONE 2494-5*

MIP

Manufacturers of Ammeters, Voltmeters, Ohmmeters, Wattmeters and frequency meters for switchboard or portable use.

MULTI-RANGE TEST SET SERIES 100

The universal testing set for Service Engineers. Sensitivity—10,000 ohms per volt. Strong metal case with carrying handle, complete with leads having detachable bulldog clips and test prods. Size 9 × 5¼ × 4 ins.

MEASURING INSTRUMENTS (PULLIN) LTD
Electrin Works, Winchester St., London, W.3
Tel.: ACOrn 4651/3 & 4995.

RANGES

AC/DC VOLTS: 10, 25, 100, 250, 500, 1,000.
DC MILLIAMPS: 2·5, 10, 25, 100, 500.
AC/DC MICROAMPS: 100 Microamps 10v range.
RESISTANCE RANGES: 0/1 Meg. (13,500 ohms mid-scale) 0/10,000 ohms (135 ohms mid-scale).

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

Laboratories, are now available for offer to successful applicants, and this offer can only remain open for a few months. Applicants' holiday requirements will receive special attention. Reply stating age, qualifications and experience to Personnel Manager. Ref. R.G. W 2504.

ELECTRONIC ENGINEERS required by J. Langham Thompson Ltd., Springland Laboratories, Bushey Heath, Herts. (i) Section Leader with a minimum experience of 5 years, preferably on government development projects. (ii) A technical writer. Apply in writing stating age and experience to Chief Engineer. W 2562

ELECTRONIC ENGINEERS required for test and inspection of experimental and prototype equipment. Applicants should have sound technical knowledge with wide practical experience. Please apply in writing with full details to Personnel Dept., ED/115, Eng. Dev. Ltd., Hayes, Middlesex. W 2579

E.M.I. INSTITUTES, Attending Division (Principal: Professor H. F. Trewman, M.A., M.I.E.E., M.I.Mech.E., M.Brit.I.R.E.), The expansion of our Four-Year courses has created a vacancy for an assistant Lecturer, Grade B, for work in the first instance with Three-Year and One-Year courses. Applicants for this post should be between 23 and 30 years of age and be graduates in Electrical Engineering, possessing industrial experience in Communications or Electronics, with preferably some instructional experience. The post is permanent with a generous pension scheme associated. Salary is in accordance with London Burnham (Technical) scale, £490-£765 per annum with appropriate allowances for training, experience, etc. Applications, stating age, qualifications and experience with the names and addresses of two persons to whom reference may be made should be sent to: The Principal, E.M.I. Institutes, 10, Pembridge Square, London, W.2. W 2574

E.M.I. Engineering Development Limited have two vacancies for electronic engineers for development work on Car Radio and Magnetic Tape recording equipment. Applicants should have sound basic training in electronics with experience in the design and development on kindred equipments. Positions offer good salaries and prospects. Please apply in writing to the Personnel Dept. (ED/123), E.M.I. Eng. Dev. Ltd., Hayes, Middlesex. W 2581

ENGINEER required to undertake the development of electronic instruments. The successful applicant must be capable of working substantially on his own initiative. Salary will be in accordance with qualifications and experience. Degree or equivalent preferred. Apply in writing to Advance Components Limited, Back Road, Shernhall Street, London, E.17. W 2553

EXPERIENCED FAULT-FINDERS wanted by Midland Manufacturers of Radio Equipment. Permanent posts located in the Midlands are offered to men with experience of Radar, Radio Control, V.H.F. Equipment. Write stating fully, experience and salary required to Personnel Manager, Box No. W 2514.

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers, wirers and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

EXPERIENCED VALVE ENGINEER required at Standard Telephones and Cables Limited, Ilminster, Somerset, to fill responsible post. Preference given to man with 1st or 2nd Class Honours. Salary according to qualifications. W 2506

GUIDED WEAPONS. Electrical Engineer or Mathematician with relevant postgraduate experience, required for theoretical work on design of automatic control systems. Some knowledge of effect of noise on servomechanisms an advantage. Senior staff appointment with good salary and prospects. Pension scheme. Write in detail to Personnel Manager, de Havilland Propellers Ltd., Hatfield, Herts. W 2488

H. M. HOBSON LTD., Fordhouses, Wolverhampton have immediate vacancies for two Electronic Engineers with sound knowledge of frequency and voltage regulation, small electronic servo-systems, pulse and strain-gauge techniques. Some experience in electronic instrumentation would be an advantage. Applicants must be British and be graduates of the Brit.I.R.E. or possess equivalent qualifications. Age 20-30. Apply stating age, experience and salary required. W 1783

KELVIN & HUGHES LIMITED. Research Laboratories at Dunmow, Essex, have a number of vacancies for Qualified Technicians dealing with Electronics, Microwaves and Electromechanical devices. These laboratories are ideally situated in pleasant country within easy reach of town and main line services. Houses are being erected locally by the Company. These are key posts open to suitable engineers, salaries commensurate with worth will be offered and future prospects are excellent. Apply in strict confidence detailing experience, qualifications, etc., to The Personnel Manager, Kelvin & Hughes Limited, New North Road, Barkingside, Essex, marking the envelope "Senior Engineers". Box No. W 2571.

LABORATORY ASSISTANTS required, male or female, for research work on solid dielectric and electrolytic capacitors. H.N.C. or Inter B.Sc. Chemistry or Physics or a recognized equivalent essential. Write, giving full details of age, education and experience, to A. H. Hunt (Capacitors) Ltd., Bendon Valley, Garratt Lane, Wandsworth, S.W.18. W 2585

McMICHAEL RADIO LTD. require Senior and Junior Engineers in their equipment division laboratory at Slough. Training and experience in the field of applied electronics (including communications) and experience of working with Government Departments are the chief qualifications required. Write stating age and full details of training, qualifications and experience to the Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 157

MECHANICAL ENGINEER required by Kelvin & Hughes Ltd., Research Laboratories, Dunmow, with good basic training and experience. Applicants should also be familiar with electronics and be able to design small mechanisms both with and without electronic devices and to design equipment of the radar type gear from a layout and presentation viewpoint. Written applications should be made, in the strictest confidence, to Personnel Department, Kelvin & Hughes Limited, New North Road, Barkingside, Essex. W 2570

MICROWAVE ENGINEERS with experience of component design, and Transformer Designers, with up-to-date knowledge of modern trends in materials, are offered exceptional opportunities for advancement with a rapidly expanding firm of Electronic Engineers. Salaries, which will be commensurate with the degree of experience, are attractive and the prospects are excellent. Apply giving full details to the Personnel Manager, Permanex Products Ltd., St. Ives, Hunts. W 1795

MUIRHEAD & CO. LTD., Precision Electrical Instrument Makers, Beckenham, Kent, require a Technical Writer to assist in the preparation of technical publications and operating instructions for electrical and electronic measuring instruments, picture telegraph apparatus and Magslips. Degree or H.N.C.; some design experience preferable; writing experience essential. Apply giving full particulars of age, experience and salary required to the Personnel Manager. W 2568

MULLARD EQUIPMENT LIMITED require for their Line Transmission Dept., a Senior Transmission Engineer for development work on multi-channel carrier telephone systems. Applicants should possess a Degree or equivalent with suitable experience. Permanent progressive positions. Superannuation, Canteen, etc. Apply in writing to: Personnel Dept., Mullard Equipment Ltd., 51/55, Garratt Lane, S.W.18. W 2535

MURPHY RADIO LTD. have vacancies for two or three Senior Engineers to lead development teams in their Electronics Division. Applications are invited from men with Engineering or Physics Degrees or equivalent, and with first class experience in the fields of Radar Navigational Aids, V.H.F. Communication Receivers and Low Power Transmitters. Salary upwards of £650 per annum according to qualifications and experience. Candidates prepared to bring energy and drive to their work may address their applications in confidence to the Personnel Manager, Murphy Radio Ltd., Welwyn Garden City. W 2587

PHYSICIST wanted by large Coventry engineering company. Applicant must hold B.Sc. or equivalent, and have experience or specialized in instrumentation. Good conditions, salary and prospects. Apply stating details of age, education and experience, etc. Box No. W 2560.

PHYSICIST required in the North West for the development of Capacitors for use in Telecommunication equipments, including silvered mica and paper and plastic dielectric types. The posts available are permanent, on full staff status, with contributory Pension Fund, etc. Please write giving full details of qualifications and experience and approximate salary required to Box No. 260, Dorland Advertising Limited, 18/20, Regent Street, London, S.W.1. W 2561

RADAR TEST ENGINEER, fully experienced, required. Full responsibility adjustment, testing and installation complete short range marine radar sets. Old-established large organization Medway Area. Write full details and salary to Box E.517, c/o 191, Gresham House, E.C.2. W 2588

RADAR SYSTEMS ENGINEER. Decca Radar Limited have a number of senior and junior posts available for radar systems engineers in their Tolworth Laboratories. Candidates must be willing to travel when required and be of British Nationality. Preference will be given to candidates who have H.N.C. or equivalent and who have had experience on the field trials and maintenance of radar equipment. The chances of rapid advancement are good. Apply, Ref. CPH/B, Decca Radar Ltd., Research Laboratories, 2, Tolworth Rise, Surbiton, Surrey. W 175

RADIO COMMUNICATIONS ENGINEER required for Customer Liaison duties in Southern England. Age 26 to 35. Knowledge of Company's products essential. Write fully to Personnel Manager, Marconi Instruments Limited, Longacres, Hatfield Road, St. Albans, Herts. W2550

RADIO & RADAR TESTERS. First class men required to work on V.H.F. Communication Gear and Government Contracts for Radio and Radar Equipment by Midland Manufacturers. Men with wide experience of Fault Finding in any of the fields mentioned should write giving full details to Box No. W 2513.

SALES MANAGER required by long established London Company manufacturing public address and allied equipment. Excellent opportunity for energetic man capable of formulating successful selling policy. Applicants should have experience in a similiar trade and be able to justify a four figure salary. Write Box No. W 2554.

SENIOR, Intermediate and Junior Draughtsmen required by The English Electric Co., Ltd., Luton, for work on design of specialized electronic equipment. Applicants should have sound mechanical background and an interest in electrical or electronic work. Part time study for National Certificate encouraged. Applications from practical engineers without Drawing Office experience will also be considered for full time training course. Remuneration according to qualifications and experience. Applications to Central Personnel Services, The English Electric Co. Ltd., Marconi House, 336/7, Strand, London, W.C.2, quoting reference 144J. W 2439

SENIOR & JUNIOR Development Engineers required for responsible work in Radio and Television Laboratories. Applicants for Senior position should be able to undertake Development work with the minimum supervision. Excellent conditions and salary available for applicants who are accepted. Apply in first case to Personnel Manager, (Dept. R.D.) McMichael Radio Ltd., Wexham Road, Slough, Bucks. Applicants must be of British Nationality. W 2567

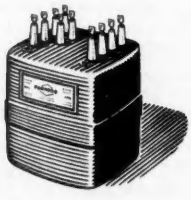
CLASSIFIED ANNOUNCEMENTS
continued on page 6

Astride Time and Space

Behind the ability to cross continents and gain a quarter of the clock in a radio-telephone call to Calcutta lies the efficiency of a highly organised system.

Telecommunications depend upon team work: this demands devotion to duty and unfailing skill from every person, every *part*, in the plan.

Parmeko, whose role in the vast network is the comparatively small one of supplying transformers, are nevertheless proud of their selection to such a splendid team. They are confident that the reliability of their products will continue to assure them their small but respected place.



PARMEKO *of* LEICESTER

Makers of Transformers for the Electronic and Electrical Industries

*Photograph by courtesy H.M. Postmaster-General

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

SENIOR ELECTRONIC ENGINEER required to prepare plans for production of Electronic Accounting Machines. Applicants should be of Degree standard and have had at least 3 years' experience of pulse techniques. Write stating age, qualifications, experience and present salary to Personnel Officer, British Tabulating Machine Co., Ltd., Icknield Way, Letchworth, Herts. W 1794

SENIOR ENGINEER with several years' experience of television receiver design is required by a manufacturer in South West London. Write giving full details of experience and salary required to Box No. W 2498.

SENIOR MECHANICAL DESIGNER. Two or three vacancies exist in our Electronics Division for Senior Design Draughtsman on Electronic Equipment. Candidates should be of at least Higher National Certificate standard and should be capable of leading a design team in this class of work. Salary £650 per annum upwards according to qualifications and experience. Applications should include full details of experience to date and may be forwarded in confidence to the Personnel Manager, Murphy Radio Ltd., Welwyn Garden City. W 2586

SENIOR TELEVISION ENGINEER of Degree Standard required by expanding firm in the Harrow District of Middlesex. Applicant to be experienced in receiver design and development. Write stating age and experience to Box No. W 1786.

SENIOR & JUNIOR Radio Development Engineers: Preferably with Higher National Certificate or equivalent. Write stating age, experience, qualifications, etc., to the Personnel Manager, Bush Radio Ltd., Power Road, Chiswick, W.4. W 2597

TECHNICAL AUTHOR required for expanding Technical Publications Department of large Electronic Organization in S.W. London. Experience of Telephone Carrier systems is desirable but an opportunity will be given to deal with wide range of Electronic Equipment. Write giving age and full details of education, qualifications and previous experience to Box No. W 2601.

TECHNICAL SALES REPRESENTATIVE, 25/35, with a knowledge of electronics and preferably the applications of electrical ceramics required for extensive travelling. A good salary and prospects for first-class man. Write fully. Box No. W 2556.

TEST ENGINEERS are required to assist in the production of a variety of precision electronic laboratory instruments. Previous Test Department experience essential, (preferably in connexion with electronic measuring instruments). Salaries in the range £440-£520 p.a. according to qualifications and experience. Apply stating full details to the Chief Engineer, Furzehill Laboratories Ltd., Boreham Wood, Herts. W 172

THE ENGLISH ELECTRIC CO. LTD., Luton, have a vacancy for a Designer of low power (up to 1 kW) low frequency Transformer and chokes. Previous experience very desirable and applicant should be thoroughly familiar with winding and impregnation processes. Varied interesting work involving development of a number of designs for small quantities. Apply quoting Ref. No. 1137 to Dept. C.P.S. 336/7, Strand, W.C.2. W 2524

THE ENGLISH ELECTRIC CO. LTD., Luton, wish to extend their present laboratory facilities for study of the effect of environment conditions on Guided Weapons and their components. Applications are therefore invited from Senior and Junior Engineers to direct and carry out this work. A wide variety of electrical, mechanical and physical testing is under consideration and although previous experience of Guided Weapons is desirable, it is by no means essential. The possession of an Engineering or Physics Degree or similar qualification, coupled with some experience in designing and handling ingenious electrical and mechanical test contrivances, would form a satisfactory qualification. Please write, stating age, experience and qualifications and salary required to Dept. C.P.S., 336/7, Strand, W.C.2, quoting Ref. 1149. W 2584

THE ENGLISH ELECTRIC CO. LTD., Luton, have vacancies for Electronic Engineers for work in Australia on V.H.F. Sub-miniature equipment with Trials applications. Assistance with housing will be provided. Applications stating age, experience and qualifications should be sent to Central Personnel Services, 336/7, Strand, London, W.C.2, quoting ref. 456. W 2468

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Coventry, requires Senior and Junior Electronic Development Engineers for work on Guided Weapons and like projects, particularly in the field of Microwave and Pulse Applications. Mechanical Development Engineers, Designer Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments, also required for the above projects. Salary according to age, qualifications and experience. Houses available for selected senior staff. Apply by letter stating age and experience to the Personnel Manager (Ref. R.G.). W 169

TRANSDUCER DEVELOPMENT. Technical assistant required in small but rapidly expanding unit. Permanent position with very good prospects. Apply in writing stating age and experience to Chief Engineer, J. Langham Thompson Ltd., 88, High Road, Bushey Heath, Herts. W 2589

WAYMOUTH GAUGES & INSTRUMENTS LTD., a subsidiary company of Smiths Aircraft Instruments Ltd., have vacancies in their Aircraft Fuel Gauge Laboratory for Assistant Engineers, required for development of electronic fuel gauging equipment. They should have an engineering Degree or Higher National Certificate. Technical Assistants are also required for experimental work in electrical measurements; preference will be given to applicants holding a technical qualification. Apply in writing to the Chief Development Engineer, Waymouth Gauges & Instruments Ltd., Station Road, Godalming, Surrey. W 2558

WAYNE KERR have the following vacancies: (a) Microwave Engineer to work on the design and development of X band and associated equipment. (b) Junior Engineers and Technical Assistants to take part in circuit design and development of test equipment ranging from Audio to S Band. Applicants for post (a) should be to B.Sc. standard, and be familiar with microwave theory. Applicants for post (b) should be to H.N.C. standard. Consideration will be given to applicants with considerable practical experience who have not achieved these qualifications. Write to The Wayne Kerr Laboratories Ltd., Sycamore Grove, New Malden, Surrey. W 2595

YOUNG ENGINEERS with good technical knowledge and some experience required for interesting work in connexion with the design and manufacture of scientific instruments. Apply to Cambridge Instrument Co. Ltd., Sydney Road, London, N.10. W 1790

YOUNG MAN with sound technical education required by Unicam Instruments Ltd., Arbury Works, Cambridge, for installation and maintenance of scientific equipment in university and industrial laboratories. Thorough training will be given to selected applicant. Write in first instance to Personnel Manager, giving age, full details of education, and previous experience, if any. W 2598

Further "Situations Vacant" advertisements appear in display style on page 79.

SITUATIONS WANTED

DEVELOPMENT ENGINEER, B.Sc., M.I.E.E. 20 years' experience instruments, test gear, components, electro-mechanical devices, nuclear physics, etc., seeks change. Part-time considered. Preferably London area. Box No. W 1735.

PUBLIC SCHOOL MAN, 28, has H.N.C. and 10 years' practical experience in telecommunications and electronics applied to research, desires post leading to executive position. Box No. W 1793.

SOLICITOR, age 29, keen electronics, photography, wishes post in secretarial or other department of firm engaged in electronic or other engineering where experience would be useful. Box No. W 1792.

AGENTS

MANUFACTURERS AND DISTRIBUTORS of first-class electronic, transmitting and p.a. equipment desiring representation in S.W. England should contact advertiser with own clerical, transport and storage facilities. Box No. W 1791.

FOR SALE

A HIGH VACUUM Impregnation Unit—to R.I.C. Specification 214 or individual requirements. Good delivery at competitive prices from Blickvac, 505, Lordship Lane, S.E.22. Forest Hill 7089. W 166

BOUND COPIES: Electronic Engineering 1945-1951, Wireless World 1945-1947, Proc. I.E.E. Part III (Radio) 1949-1952, Journal Brit. I.R.E. 1945-1952, Journal Television Society 1951-1952. (Dates inclusive.) Offers to Box No. W 1801.

ELECTRONIC COMPONENT SUPPLIES. We specialize in the supply of Electronic Components, Accessories, Test Equipment, etc., for Government Depts., Industrial Concerns, Research Establishments, Laboratories, Colleges, etc. Your enquiries and orders will receive our prompt attention. Holiday & Hemmerdinger Ltd., 74/78 Hardman Street, Deansgate, Manchester, 3. Tel.: Deansgate 4121. W 148

MAGSLIPS at 1/10th to 1/20th of list prices. Huge stocks. Please state requirements. K. Logan, Westalley, Hitchin 1744, Herts. W 116

MINIATURE BALL BEARINGS, Steel Balls, Stainless Steel and Phosphor Bronze Balls. Prompt delivery. Distributors: Insley (London) Ltd., 21/22 Poland Street, London, W.1. Tel.: GERrard 8104 and 2730. W 155

SINE-COSINE Potentiometers, Magslips, Selsyns, Ipots, Velodynes and equipment and components for automatic control. Servotronic Sales, Inc. Hopton Radio, No. 1 Hopton Parade, Streatham High Road, London, S.W.16. STReatham 6165. See our advertisement on page 78. W 2502

SINE-COSINE RESOLVERS (3" Magslip Transmitters No. 5, AP 10861). Brand new, each in maker's tin. Offered in quantity at less than one tenth of cost. Export inquiries invited. P. B. Crawshay, 166 Pixmore Way, Letchworth, Herts. W 153

WEBB'S 1948 Radio Map of the World, new multi-colour printing with up-to-date call signs and fresh information; on heavy art paper 4s. 6d., post 6d. On linen on rollers 11s. 6d., post 9d. W 102

SERVICE

CORNER REFLEX CABINETS for Goodmans 12-in. Loudspeakers from £10 0s. 0d. Cabinets and Cases made to order. Call or write, A. Davies & Co., Cabinet Makers, 3 Parkhill Place, off Parkhill Road, London, N.W.3. GULliver 5775. W 1797

GLASSBLOWING. High Vacuum, Chemical, Glass-Metal Seals, Research Apparatus. Prototype or long runs. Capacity available. H. Stanley, 129, Lower Addiscombe Road, Croydon. ADD. 7193. W 1691

MANUFACTURERS. As specialists in all types of Sheet Metal Work for the Radio and Electrical Trade we are able to quote you very keen prices for a high quality job. Intensalite Sign and Fixture Co. Ltd., 89, Leopold Street, Birmingham, 12. Telephone Vic. 0065. W 1684

METALWORK. All types cabinets, chassis, racks, etc., to your own specifications. Philpott's Metal Works Ltd. (G4BI), Chapman Street, Loughborough. W 2197

CLASSIFIED ANNOUNCEMENTS
continued on page 8

S·L·I offer an ideal combination . . .

providing R.F. power for driving transducers and R.F. bridges, also for the general development and testing of audio and video equipment. The instruments may also be used to excite M.F. aerials and feeders for radiation tests.

• 0.2 Volts input • 15 Watts output

WIDE RANGE OSCILLATOR MODEL OS.101.

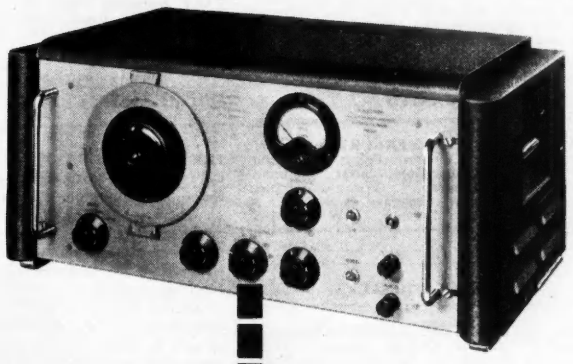
FREQUENCY RANGE :
25 c/s—250 Kc/s in 4 ranges.
Additional calibration at 300 Kc/s.

ACCURACY :
Better than 1 per cent or 1 c/s.

STABILITY :
Long term better than 0.1 per cent.

DISTORTION :
Less than 1 per cent of the total output.

HUM LEVEL :
0.1 per cent of the maximum output.



0·2 VOLTS INPUT

WIDE BAND POWER AMPLIFIER MODEL AWS.53.

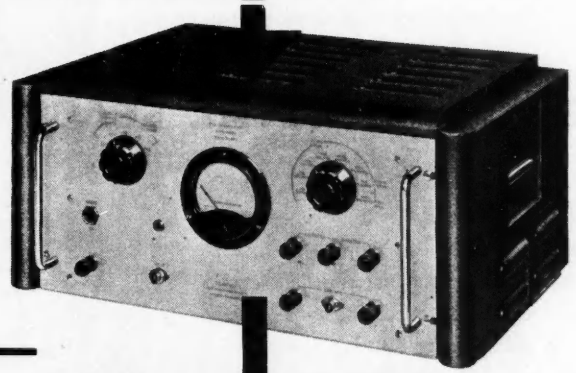
FREQUENCY RANGE :
20 c/s—3 Mc/s in three ranges.

POWER OUTPUT :
15 watts, 20 c/s—500 Kc/s.
8 watts, 20 c/s—1.5 Mc/s.

VOLTAGE OUTPUT :
150 volts push pull 20 c/s—3 Mc/s.

LOAD IMPEDANCE :
15Ω, 75Ω, 150Ω or 600Ω balanced or earthed

INPUT VOLTAGE :
0.2 volt for full output on power ranges.
0.1 volt for full deflection output.



15 WATTS OUTPUT

The new Solartron Power Amplifier when driven by the Oscillator, Model OS.101 or an H.F. signal generator, will provide an output power of 15 watts nominal between 20 c/s and 1.5 Mc/s with a choice of load impedances to suit different matching conditions. In addition, a voltage output of 150 volts push pull for C.R.T. deflection is provided with a response to transients of 0.1 microsecond.

QUICK DELIVERY FOR BOTH INSTRUMENTS

SOLARTRON

Write now for details of these and other new products to :

SOLARTRON LABORATORY INSTRUMENTS LTD.
22 HIGH STREET KINGSTON SURREY. TEL. : KINGSTON 8981 P.B.X

PLATED NUTS, Screws, Washers, Bolts, Soldering Tags, Hank-Bushes, Self-tapping screws, Grub-screws, Socket-screws, Wood-screws. Large quantities or gross cartons. Stamp for list. Sinden Components, Limited, Dept. A, 117, Churchfield Road, Acton, W.3. ACOrn 8126. W 1732

SHERWOOD INSTRUMENTS LIMITED specialize in the manufacture of instrument cases, chassis, complete mechanical assemblies. Capstan work to ¾ in. dia. Lathe and light press work. Highest standards at competitive rates. A.I.D. approved. Advisory service available. Rosemont Road, London, N.W.3. Telephone HAMpstead 6655. W 1789

SUB-CONTRACT facilities available, Radar sub-chassis, etc. Short or long runs. Complete assembly undertaken to specification. Hill & Co., Byfleet, Surrey. W 1796

TECHNICAL WRITING. Manufacturers' technical manuals and hand books, etc., prepared for press and publication. Radio light mechanism and allied subjects. Box No. W 1799.

WANTED

WANTED WASTE MERCURY. Aircraft Sparking Plugs, Contacts, Points and Scrap Materials containing Gold, Silver, Platinum, also non-ferrous scrap. Forward samples: immediate attention. Belgrave Buyers (EE), 5 Belgrave Gardens, London, N.W.8. MAI. 7513. W 1733

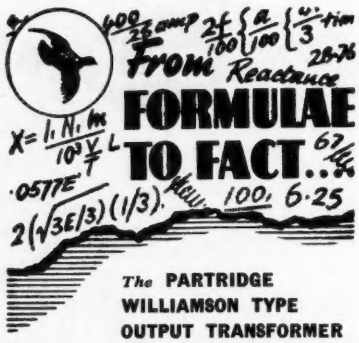
EDUCATIONAL

CITY OF COVENTRY Education Committee. Coventry Technical College. Session 1953-54. Electronic Engineering. Applications are invited for entry to the next 3-year full-time course commencing in September, 1953, from those requiring a comprehensive training to an advanced level in Electronic Engineering, to qualify them for technical posts in radio, telecommunications, television and industrial electronics. The syllabus will cover the requirements of C. & G., Brit.I.R.E., and I.E.E. examinations. Entry age 16 years or over. Application forms and further information available from the Principal, Coventry Technical College. W. L. Chinn, M.A., Director of Education, Council House, Coventry. W 1708

CITY & GUILDS (Electrical, etc) on "No Pass—No Fee" terms. Over 95 per cent successes. For full details of modern courses in all branches of Electrical Technology send for our 144-page handbook—Free and post free. B.I.E.T. (Dept. 337C), 17 Stratford Place, London, W.1. W 142

FREE. Brochure giving details of courses in Electrical Engineering and Electronics, covering A.M.Brit., I.R.E., City and Guilds, etc. Train with the Postal Training College operated by an Industrial Organisation. Moderate fees. E.M.I. Institutes, Postal Division, Dept. EE29, 43, Grove Park Road, London, W.4. (Associate of H.M.V.). W 2808

THE POLYTECHNIC, 309 Regent Street, W.1. Department of Mathematics and Physics. A course of lectures on Electronics will be held on Thursday evenings from 6 to 7.30, commencing 1st October, 1953. The course is suitable for those who wish to take this subject in the Graduateship examination of the Institute of Physics. Fee for the course, £2. A detailed syllabus of the lectures is available. Application to attend the course should be made as soon as possible to the Head of the Department of Mathematics and Physics. W 2537



The **PARTRIDGE WILLIAMSON TYPE OUTPUT TRANSFORMER**

To convert formulae to actual performance implies the use of the very highest standards in the materials and workmanship employed. Since the inception in 1947, of the now world-famous Williamson Amplifier, Partridge "to-specification" components have been the insistent choice of the experts. This transformer is available in a varied range of impedances. Secondary windings are brought out to eight separate sections of equal impedance, Stock types comprise 0.95 ohm, 1.7 ohm, 3.6 ohm and 7.5 ohm sections.

Full technical data on request.

Potted type (as illustrated) **£7 5s. 3d.**

De Luxe type **£6 16s. 6d.**

PARTRIDGE TRANSFORMERS LTD
ROEBUCK ROAD · KINGSTON BY-PASS · TOLWORTH · SURREY
TELEPHONE: ELMbridge 6737-8

36/NL/6

GLASS-TO-METAL SEALS

The Nilo* series of nickel-iron alloys has been developed for applications where controlled low and intermediate coefficients of thermal expansion are required, as in glass-to-metal seals, thermostats and machine parts where changes in dimension are undesirable and must be closely controlled.

Details of their expansion characteristics are contained in our publications. May we send you copies ?

* *Registered Trademark.*

"The Nilo Series of Controlled Expansion Alloys"
A reference book giving physical properties and expansion curves for the Nilo Alloys.

"Glass-to-Metal Seals"
Subjects dealt with include: Types of Seals, Sealing Alloys, Mechanism of Sealing, Stresses.

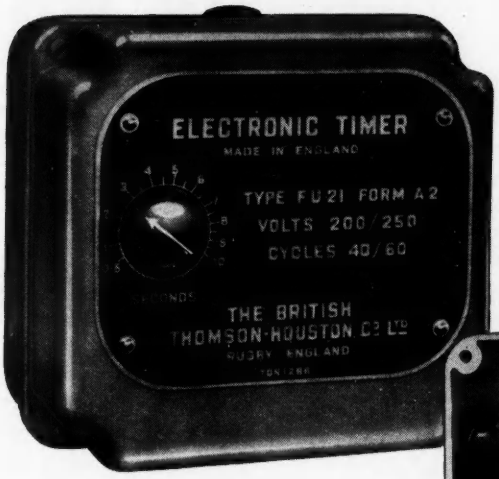
HENRY WIGGIN & COMPANY LIMITED, WIGGIN STREET, BIRMINGHAM, 16

Electronic Timer

The BTH Electronic Timer provides an ideal method of accurate timing for industrial and laboratory processes where high precision is required. The timing period is initiated by closing a simple control switch of the 'ON'–'OFF' pattern—or alternatively by employing a pair of contacts, opening and closing automatically—remaining closed throughout the timing period.

TIMING RANGES (IN SECONDS)

TYPE FU21, FORM	A1	A2	A3	A4	A5	A6	A7	A8
Minimum setting (in secs.) ...	0.3	0.5	1	1.5	4	6	8	12
Maximum setting " " ...	5	10	20	30	60	90	120	180

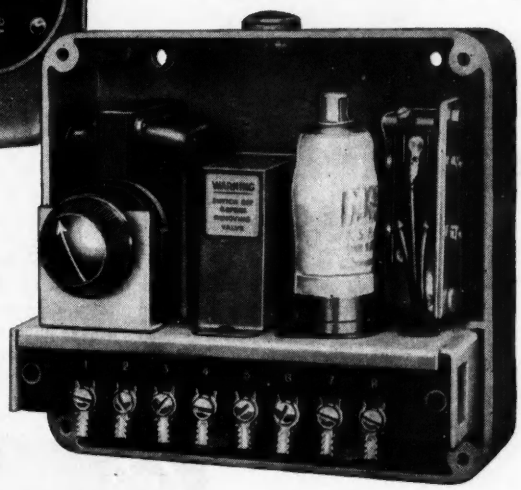


SUPPLY:

200/250 volts. 40/60 cycles, A.C.

CONTACT RATINGS:

4 amperes at 250 volts A.C. and 2 amperes at 440 volts A.C. (on D.C. circuits, rating depends very largely on the nature of the load) single-pole, double-throw.



FEATURES

- No moving parts except small control relay.
- Convenient and stepless variable time adjustment.
- Standard radio valve used.
- Chassis easily withdrawn—only one screw to remove.
- High accuracy of repetition.
- All components of proved reliability.
- Location and installation easy owing to the small overall dimensions.

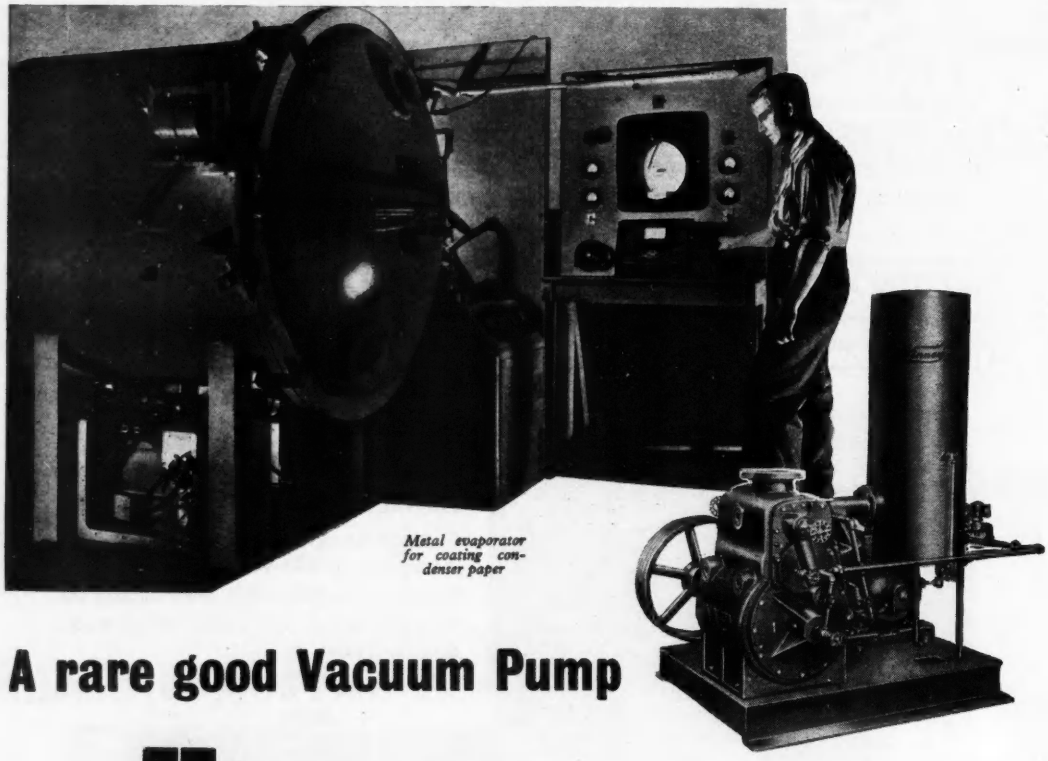
BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO., LTD., RUGBY, ENGLAND

Member of the AEI Group of Companies

A3954

For a good rare atmosphere



Metal evaporator for coating condenser paper

A rare good Vacuum Pump

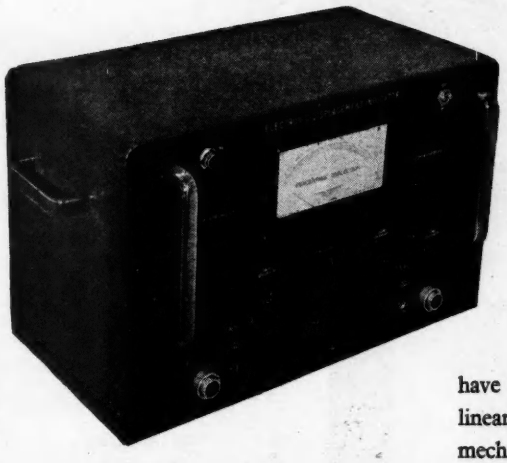
. . . Kinney

Many of to-day's products take shape through being processed in atmospheres rarefied by Kinney Vacuum Pumps. Penicillin, titanium, cathode ray tubes, coated mirrors and lenses, blood plasma, dehydrated foodstuffs and oils, metal coated foils and condenser papers, orange juice, electrical impregnated components, "improved" wood, are a few examples. Wherever vacuum processing is applicable, Kinney pumps give the lowest cost results.

GENERAL ENGINEERING CO (RADCLIFFE) LTD.

GENERAL ENGINEERING CO. (RADCLIFFE) LTD., Station Works, Bury Road, Radcliffe

Telephone RADcliffe 2291/3 (3 lines) London Office: 3rd Floor, 9 Victoria Street, London, S.W.1. Tel.: ABBey 5278

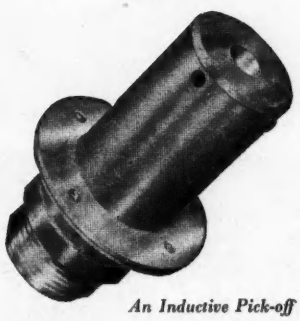


The Saunders-Roe Displacement Indicator

This instrument and its associated pick-offs have been designed to afford a degree of stability and linearity of calibration at least as good as that of a mechanical extensometer. In addition the maximum possible measuring flexibility and adaptability have been incorporated. It is normally supplied for two channel working but additional channels up to a total of six can be made available if desired. Displacement is indicated as deflection on a panel mounted 0-1 milliameter and additional facilities are provided to connect the output stages to suitable direct recording equipments.

THE PICK-OFFS

In order to secure linearity of calibration within a wide working range, the pick-off unit consists electrically of a constant impedance inductive half-bridge unbalanced by movement of a magnetic material in proximity to the inductive elements. Whilst this system is considerably less sensitive in terms of mechanical displacement/electrical output than the conventional differential transformer, it does provide extremely good linearity over a wide range, which is considered to be a prime feature in this type of equipment. The pick-offs may be used singly or in pairs. Paired use is a particularly valuable application, for instance, in process control, where dimensional monitoring is required in the absence of a convenient datum, e.g. plastic extrusion, wire drawing, foil rolling, etc.



An Inductive Pick-off

GENERAL SPECIFICATION

The instrument is engineered to the standard of robustness necessary for general industrial use. All electronic circuits are carefully stabilised against mains supply variations, and components are of high quality and stability. All Sales are subject to the Company's Standard Conditions.

INSTRUMENT

Dimensions: Height: 10.5 in. Length: 17 in. Depth: 9 in.
Weight: ... ... 33.5 lb. (15.3 kg.)
Power Supply: ... ... 115-230 volts, 50-60 c.p.s. A.C.
Measuring frequency and range: ... Max. 600 c.p.s.
Measuring ranges:... ... ... 0-.005", 0-.015", 0-.050".
Other ranges available: ... ... 0-0.10"

PICK-OFF

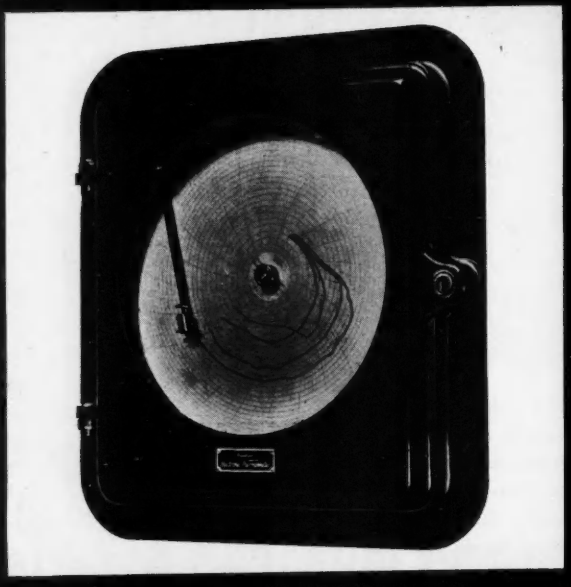
Dimensions: ... ... Length: 2.35 in. Dia: .90 in.
Mounting flange: 1.30 in. dia.
Weight: ... ... 57.5 grams.
Weight of moving element: ... ... 2.5 grams.

SAUNDERS ROE LTD

ELECTRONICS DIVISION

OSBORNE • EAST COWES • ISLE OF WIGHT

Higher accuracy in recording, indicating and control of temperature is achieved at Lower cost by . . .



THE FIELDEN ELECTRONIC THERMOMETER

Compare these advantages with any other method of temperature measurement

- Long term high accuracy and reliability.
- Simple design—easy, inexpensive maintenance.
- No galvanometers or fragile mechanisms.
- Interchangeability of resistance bulbs to standard—without recalibration.
- Cold-End compensation eliminated.
- Power operated recording mechanism.
- Rapid pen response.
- Reduce thermal lag.
- Distant Indication. No restrictions due to use of capillary tubing.
- Continuous balancing.
- No batteries required.
- Low capital cost.

Full technical details are contained in an illustrated 23 page booklet which is available on request.
Send for Publication No. 209/FE.

Fielden INSTRUMENTATION

FIELDEN (ELECTRONICS) LTD.

WYTHENSHAWE, 3, MANCHESTER.

Telephone: WYThenshaw 3251 (4 lines). Telegrams: Humidity, Manchester.

LONDON OFFICE: 21 BUCKINGHAM ST., W.C.2. Telephone: TRAfalgar 3154

There is a FIELDEN INSTRUMENT for most physical measurements

No.5

Screw a
plete, r
handling
costly a
is dropp
Easily h
wasted
correct
indentin
in our s
is upon
those tw
thing Li

I I

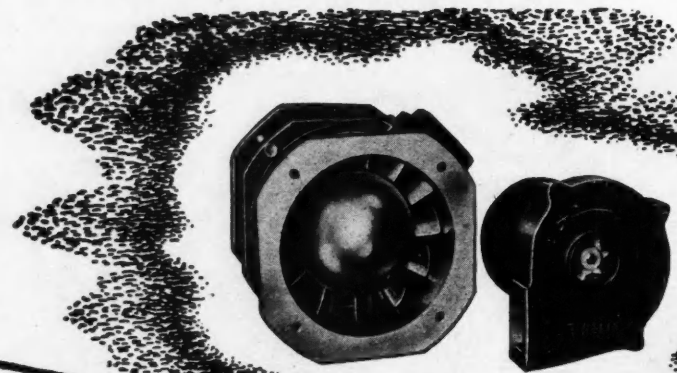
THESE ARE OUR PRODUCTS

No. 5 sems

Screw and washer assembled to form one complete, ready-to-use component, requiring one handling operation and eliminating tedious and costly assembly by hand. As soon as a Sems is dropped into position it is ready for driving. Easily handled and fast to drive. No lost or wasted washers and each screw fitted with the correct type and size of washer. Simplifies indenting and stock-keeping too. This is No. 5 in our series of advertisements and the emphasis is upon time-saving. Of course, there are again those two all-important factors that stamp everything Linread make and do. Quality and Service.

Linread

LINREAD LTD · COV ST · BIRMINGHAM 7



electronic COOLING

The wide range of blowers for force-cooling of valves and maintenance of desired temperature levels in electronic and general electrical apparatus is typical of the progress maintained by ACI *The illustration shows the smallest of the blowers (4" Axial Flow type and 2½" Centrifugal type), but our range covers duties from 5 c.f.m. up to many thousands of c.f.m. at pressures up to 45 or more inches w.g. These blowers are used in MARINE & AERODROME RADAR INSTALLATIONS, AIRCRAFT AUTOMATIC PILOTS, COMMUNICATION AND BROADCASTING STATIONS, R.F. HEATING EQUIPMENT, Etc. Let us know your application—we shall be pleased to put forward our proposals.*

ACI

Complete Air Treatment Plant

AIR CONTROL INSTALLATIONS LTD.

RUISLIP MIDDX.

Telephone: Ruislip 4066 (8 lines) Telegrams: Controlair, Ruislip

BIRMINGHAM MANCHESTER GLASGOW

Precision in process control

The Ignitron is designed for precision control of processes involving the use of comparatively low voltages and high currents—for example, resistance welding and X-ray exposure control. It exhibits some important advantages over other methods; the ignitron combines the precision and freedom from mechanical problems of the thermionic valve with the robustness of the contactor; it is compact, moderate in weight and has a long life. 'ENGLISH ELECTRIC' Ignitrons are made in a range of standard sizes, interchangeable with all other types in common use. They can be water-cooled and are suitable for line voltages of 250-600 volts.

'ENGLISH ELECTRIC' ignitrons

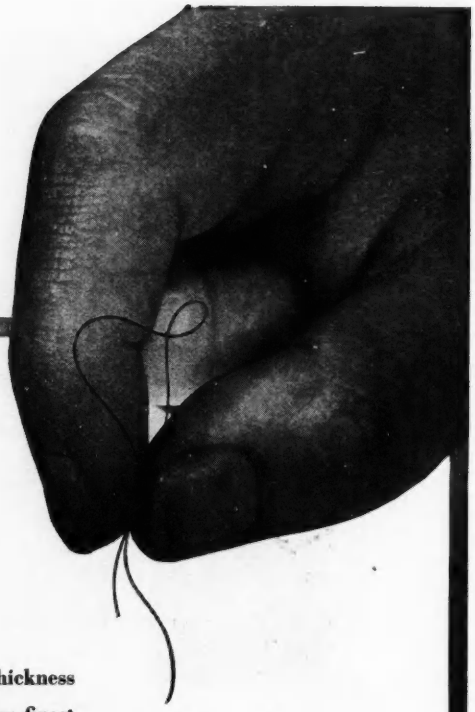
ENGINEERING, MARINE & WELDING EXHIBITION: OLYMPIA—SEPT. 3rd-17th—Visit our Stands

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

Rectifier Sub-station Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY BRADFORD · LIVERPOOL · ACCRINGTON

I.G.I.



Quarter the thickness of a human hair

The average human hair is $^{4}/_{1000}$ of an inch in thickness (·004" diam. if you'd rather be technical) and our finest enamelled copper wire is only $^{1}/_{1000}$ when insulated with five separate coats of enamel ; one pound of it would measure 316,000 feet, or some 60 miles. Amazingly fine in every way — it must be of course to bear the name Connolly. Let us know if you'd like further details of this or any of our other winding wires.

The largest manufacturers of fine enamelled wire in the world.

CONNOLLYS (BLACKLEY) LTD., MANCHESTER, 9

Telephone: CHEETHAM HILL 1801 **Telegrams: "CONNOLLYS BLACKLEY"**

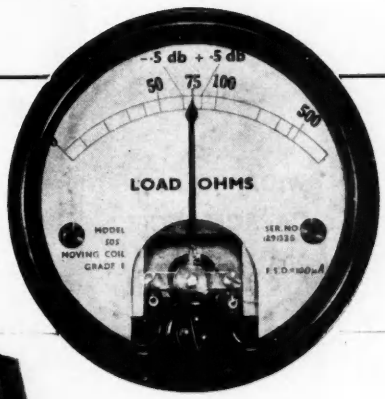
LONDON OFFICE:
34, Norfolk Street,
STRAND W.C.2 TEMple Bar 5506

BIRMINGHAM OFFICE:
15-17 Spiceal Street,
BIRMINGHAM, 5 Midland 2268

Output Level Stabilised to ±½db

OVER THE FULL FREQUENCY RANGE OF 10 Kc/s — 10 Mc/s

An outstanding feature of the Wayne Kerr Video Oscillator Type O.222A is a thermistor bridge circuit stabilising the amplitude. Once set the output level will remain constant within 0.5 db while the oscillator frequency is varied over its full range of 10 Kc/s to 10 Mc/s. *Another advantage* is its special facility for indicating the modulus of the load impedance to which the instrument is connected.



SPECIFICATION

In transportable case £155, *or for standard* 19" *Rack mounting* £148.

Frequency Range:	10 Kc/s — 10 Mc/s in 6 ranges
Frequency Stability:	better than 1 in 10^3 in 1 hour
Frequency Accuracy:	1%
Output Range:	+10 db to −50 db on 1V p-p.
Output Level:	Constant to ±0.5 db at any frequency [setting
Output Impedance:	75 ohms
Total Harmonic Content:	less than 1%

Wayne Kerr

THE WAYNE KERR LABORATORIES LTD · NEW MALDEN · SURREY

WIDE RANGE CAPACITANCE BRIDGE

For the accurate measurement of *in situ* capacitance or resistance, all measurements being made in the form of a three terminal network.

Capacitance range — 0.002 pF to 100μF in 18 ranges.
Resistance range — 1Ω to 10,000MΩ in 18 ranges.
Ranges increase in alternate decimal multiples of 3 and 10.
Frequency 1592c/s (ω = 10,000).
Accuracy $\pm$1.0% of full scale on all ranges.

Full technical details are available on request.

CINEMA-TELEVISION LIMITED

A Company within the J. Arthur Rank Organisation

WORSLEY BRIDGE ROAD · LONDON · SE26

Telephone HITher Green 4600

SALES AND SERVICING AGENTS

F. C. Robinson & Partners Ltd., 287 Deansgate, Manchester, 3

Hawnt & Co., Ltd., 59 Moor St. Birmingham, 4

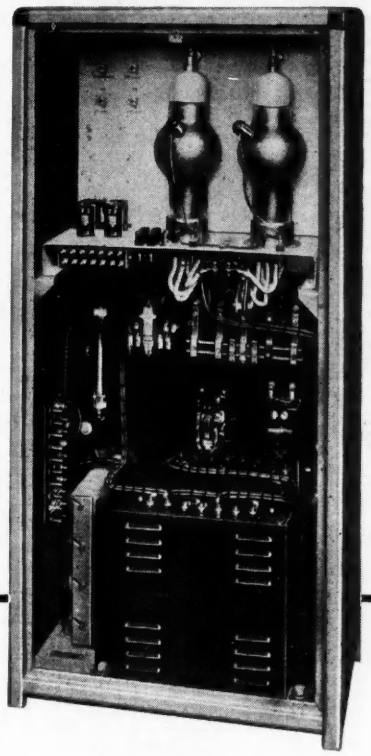
Atkins, Robertson & Whiteford Ltd., 100 Torrisdale Street, Glasgow, S.2.

The Metrovick

MAGNETIC AMPLIFIER/THYRATRON CONTROL SCHEME

Electronic control gear has been used in industry for some time to give high performance and to deal with difficult automatic control problems. Performance of fully electronic gear is often much higher than is necessary; the magnetic amplifier thyratron combination retains the advantages of electronic control technique, at the expense of slightly reduced performance, but adequate for the majority of industrial drives. Coupled with this are the advantages of greatly simplified circuitry and improved reliability.

The illustration shows a standard 5 h.p. unit as used for small printing presses, machine tool drives, or dancing roller systems of control in continuous processes such as paper and rubber manufacture.



METROPOLITAN-VICKERS ELECTRICAL CO. LTD., TRAFFORD PARK, MANCHESTER 17
Member of the A.E.I. group of companies

METROVICK *for simplification in electronics*

H/A 103

'VARIAC' voltage regulating transformers

Reg'd Trade Mark

'VARIAC' infinitely variable voltage-regulating transformers are designed and constructed for many years of trouble-free operation. Not only do they supply perfectly smooth control of voltage from zero, but many types (including 100-R) also furnish output voltages considerable above line voltage while the 100-RM/2B is a dual output type. Illustration left shows Type 100-R, Rating 2,000 va., Input Voltage 230/115, Output Voltage 0-270.

Left—
Type 200 C.U.H.

Right—
Type 50-B.

SERIES 100 'VARIAC' TRANSFORMERS.

Type	Load Rating	Specifications				No-Load Loss	Net Price ‡
		Input Voltage	Current		Output Voltage		
			Rated	Maximum			£ s. d.
100-K	2000 va.	115	15 a.	17.5 a.	0-115	20 watts	17 17 0
100-KM	2000 va.	115	15 a.	17.5 a.	0-115	20 watts	18 12 0
100-L	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	17 17 0
100-LM	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	18 12 0
100-Q	2000 va.	115	15 a.	17.5 a.	0-135	20 watts	18 9 0
100-QM	2000 va.	115	15 a.	17.5 a.	0-135	20 watts	19 4 0
100-R	2000 va.	230/115	8 a.	9 a.	0-270	30 watts	18 9 0
100-RM	2000 va.	230/115	8 a.	9 a.	0-270	30 watts	19 4 0
100-LH	1200 va.	480/240	2 a.	2.5 a.	0-480	25 watts	21 15 0
500-L	1450 va.	180	8 a.	9 a.	0-180	25 watts	17 17 0
2000-K	1000 va.	125	8 a.	9 a.	0-125	25 watts	17 17 0

* For 500 cycles † For 2,000 cycle service ‡ All 'VARIAC' prices plus 20% as from 23rd Feb. 1952

Write for catalogue V549 which gives full details of 'VARIAC' transformers and suggestions for use.

Prompt Delivery

CLAUDE LYONS LIMITED

ELECTRICAL AND RADIO LABORATORY APPARATUS, ETC.

180 Tottenham Court Road, London, W.1 ; and 76 Oldhall Street, Liverpool 3, Lancs.

New, convenient sources of β-rays for Industry, Medicine or Research

Long used by the radiotherapist and the physicist, β-rays are now becoming increasingly useful in industry—for instance in thickness gauges and static eliminators. For such applications we can now supply β-ray sources which are efficient, convenient and robust.

These sources take the form of silver foils, plaques, and wires. The radioactive isotope is firmly bonded within the metal, so that it cannot be released accidentally, and all external surfaces are free from radioactive contamination.

This technique can be applied to many isotopes, covering a wide range of physical characteristics, and in various forms. The following have been most popular so far:—

FOILS†

Strontium-90		Radium-D	
Code	Microcuries/sq. cm.	Code	Microcuries/sq. cm.
SIM 1	0.008	RBM 1	0.008
SIM 2	0.3	RBM 3	12
SIM 3	30	Cerium-144	
SIM 4	300	CHM 3	300

†*40 mm. wide × 0.15 mm. thick. Active area 25 mm. wide down centre of foil.*

PLAQUES*
Strontium-90

Code		Active Area. Sq. cm.	Activity. Millicuries.
Circular	Square		
SIP 1	SIP 2	1	5
SIP 3	SIP 4	2	5
SIP 5	SIP 6	2	10
SIP 7	SIP 8	4	10
SIP 9	SIP 10	4	20

* *(The dimensions and activities of these plaques correspond to those of the radium plaques commonly used therapeutically)*

For further information please write to:—
RADIOCHEMICAL CENTRE, AMERSHAM, BUCKINGHAMSHIRE, ENGLAND

TAS/RC.4.

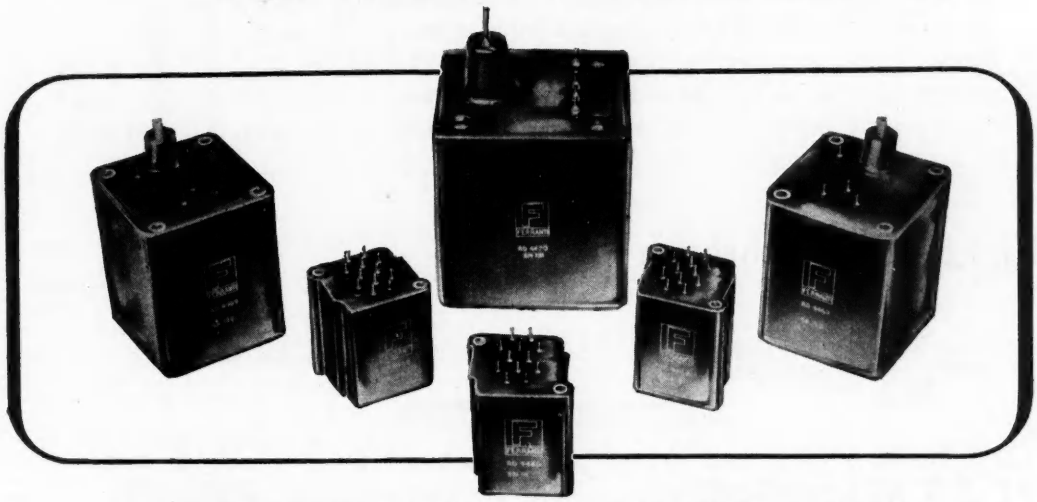
The shape of things to GO . . . .

You can now avoid the slightest risk that delicate electronic instruments will be "Damaged in Transit". HAIRLOK, which is a new form of resilient packing, ensures perfect protection because it is moulded to fit the shape of the product exactly. It can be moulded as hard or as light as required and will withstand any shock load including low frequency vibrations and varying climatic conditions. HAIRLOK complies with government specification and is non-staining to silver. To ensure that equipment is "Received in Perfect Condition" specify Hairlok packing. We shall be glad to send full details on request.

THE Hairlok COMPANY LIMITED

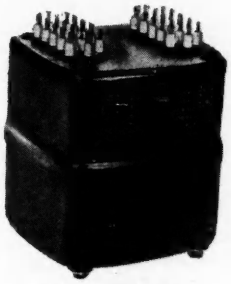
IDDESLEIGH HOUSE, CAXTON STREET, LONDON, S.W.1. TELEPHONE: ABBEY 6722

A COMPLETE TRANSFORMER SERVICE TO THE ELECTRONIC EQUIPMENT MANUFACTURER



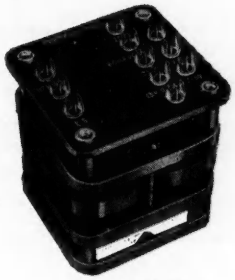
THE NEW "PENTLAND" SERIES RESIN CAST TRANSFORMERS AND CHOKES

Complete assembly sealed in resin block—suitable for incorporation in every type of electronic equipment—designed to meet, at low cost, the stringent requirements of Specification RCS 214—saving in weight and volume—suitable for power, signal, pulse and high voltage applications—designed to individual specification.



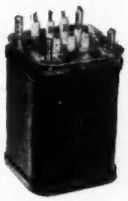
"H" SERIES

—hermetically sealed oil-filled components. "C" core construction conforming with RCL 215.



"K" SERIES

—impregnated open type "C" core construction, conforming with RCL 216.



"M" SERIES

—hermetically sealed miniature type for power and signal applications.

FERRANTI

FERRANTI

Enquiries to Technical Sales Dept.:

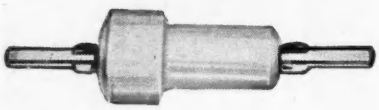
FERRANTI LTD · CREWE TOLL · EDINBURGH 5

ES/T 3

POLYTAGS... lead-through and stand-off insulators

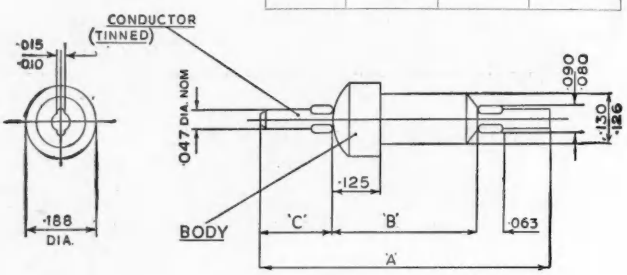
Polytetrafluoroethylene (P.T.F.E.) is an outstanding insulator. It is tough, durable and will not crack or arc. Its dielectric properties are substantially constant over a frequency range of 60 c.p.s. to at least 300 Mc.p.s. and are unaffected by temperature changes between minus 100°C. and plus 288°C. It has zero moisture absorption and is water repellent. It is, therefore, a most suitable material for stand-off and feed-through insulator terminals and has been chosen by Ediswan for this purpose. Ediswan Polytags are available in five types as illustrated below.

PT 1 & 2. Lead-through

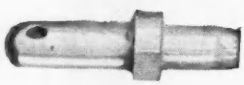


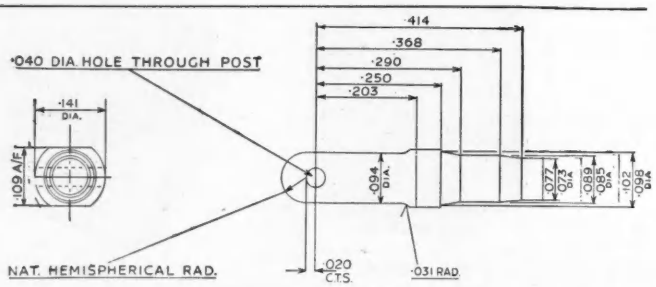
PT 3 & 4. Stand-off

	A	B	C
PT 1	.750	.375	.188
PT 2	.875	.500	.188
PT 3	.563	.375	—
PT 4	.688	.500	—



PT 5. Component mounting





Fixing: Polytags are primarily designed for fixing with a 5 B.A. nut—PT 1—4 or an 8 B.A. nut PT 5. They are self-tapping.

We are equipped to produce components fabricated or moulded in P.T.F.E. to individual specifications and enquiries will be welcomed.

EDISWAN

CLIX

THE EDISON SWAN ELECTRIC CO., LTD.,

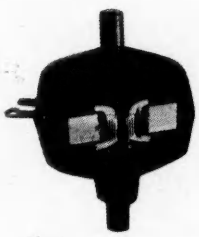
Sales Department P.T.F.E.4, 21 Bruton Street, London, W.1. *Telephone: Mayfair 5543* ER24

Head Office: 155 Charing Cross Road, London, W.C.2. *Member of the A.E.I. Group of Companies*

'Araldite'

the new epoxy resins

as in metal ferrules to 'Mycalex' insulator rods — **bonding**



as in the potting of transformers and other electrical components — **casting**

as for the protection of collapsible tubes — **coating**

'Araldite' adhesives

form of resin	curing conditions	special properties	typical applications
'Araldite' type 1	hot setting	solvent free high strength	bonding metals, ceramics and other non-porous materials
'Araldite' type 15	hot setting	thin adhesive film high strength	bonding electrical laminations
'Araldite' type 101	cold setting		bonding non-porous materials when heat cannot be applied
'Araldite' type 102	cold setting		bonding materials, one of which must be porous
'Araldite' D	cold or hot setting	solvent free, higher strength than obtainable with types 101 and 102	bonding non-porous materials

'Araldite' casting resins

'Araldite' B	hot setting	high mechanical and electrical strength low shrinkage	potting electrical equipment; pre-formed insulating materials
'Araldite' D	cold or hot setting		potting electrical equipment which cannot be heated
'Araldite' F	cold or hot setting	low viscosity	penetration into fine windings

'Araldite' fillers

'Araldite' cold setting filler		good adhesion to metals	filling depressions in metal surfaces
'Araldite' hot setting filler		solvent free no shrinkage	filling weld channels in motor car bodies

'Araldite' coating resins

'Araldite' 970 Bn	hot setting	flexibility and adhesion	coating wire for electrical industry
'Araldite' 985E	hot setting	hardness, flexibility, chemical resistance and adhesion	protection of metal surfaces (especially in paint industry)

recently developed forms of 'Araldite' for evaluation

'Araldite' flexible adhesive 33/896	hot setting	permanent flexibility	joining dissimilar materials, e.g., glass and metal
'Araldite' flexible casting resin 33/896	hot setting	permanent flexibility	potting electrical equipment in a non-rigid medium
'Araldite' expanded resin 33/912	hot setting	low weight good electrical properties	light weight core material with good electrical properties
'Araldite' impregnating resin	hot setting	low viscosity at room temperatures solvent free	room temperature impregnation

full details will be gladly sent on request

Aero Research Limited

A Ciba Company

DUXFORD, CAMBRIDGE

Telephone: Sawston 187

'Araldite' is a registered trade name of Aero Research Limited

SO 55

Who isn't on the right programme?

Are you? The frequency with which you send scrap from your works is vitally important — because roughly half this country's supplies of new steel are made from scrap. Factories like yours are among the main sources of the raw material needed in the steel-works. These sources must not be allowed to dry up.

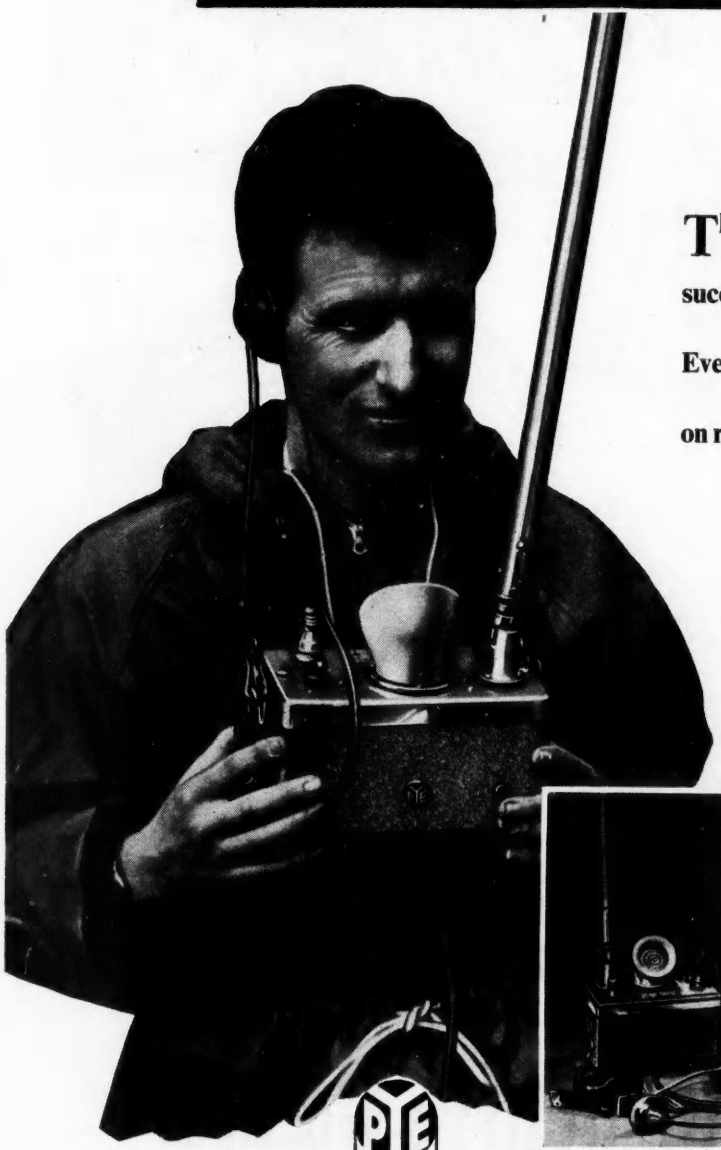
Obsolete machines and equipment, redundant buildings, in fact everything made from iron and steel which has outlived its effective purpose — all this is scrap and should be sent off to your local scrap merchant as soon as possible.

Search your works for it and turn it in. You will be doing yourselves a great service.

VISIT STAND No 12.
at the National Radio and Television Exhibition, Earls Court, Sept. 1 - 12 — and see what STEEL is doing to help the national effort.

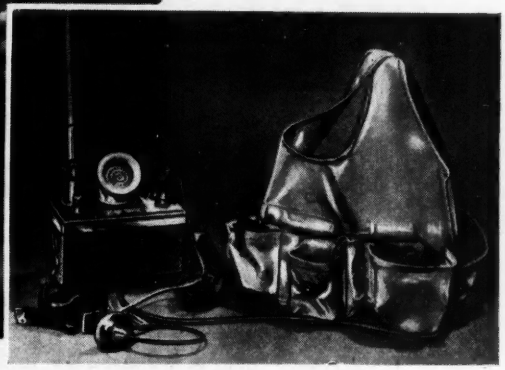
Issued for the STEEL SCRAP DRIVE by the British Iron and Steel Federation and the National Federation of Scrap Iron, Steel and Metal Merchants.

RADIO USED WITH GREAT SUCCESS HUNT



Throughout their brilliantly successful expedition the Mt. Everest team relied exclusively on radio communications equipment supplied by Pye.

Illustrated here is the lightweight V.H.F. "Walkie-phone" (5 lbs) and battery-carrying waistcoat.



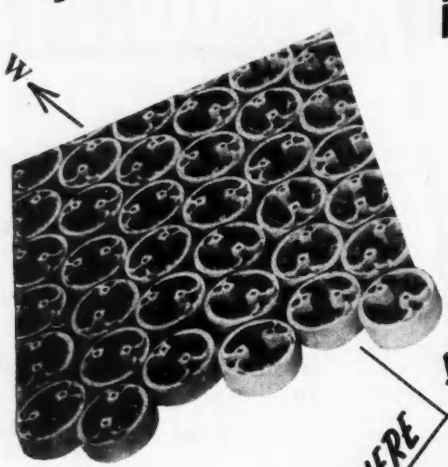
PYE

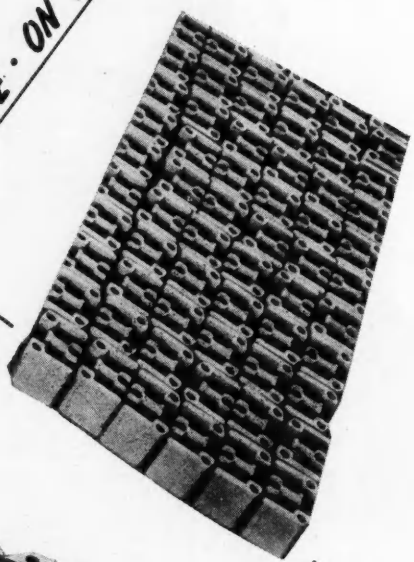
Telecommunications

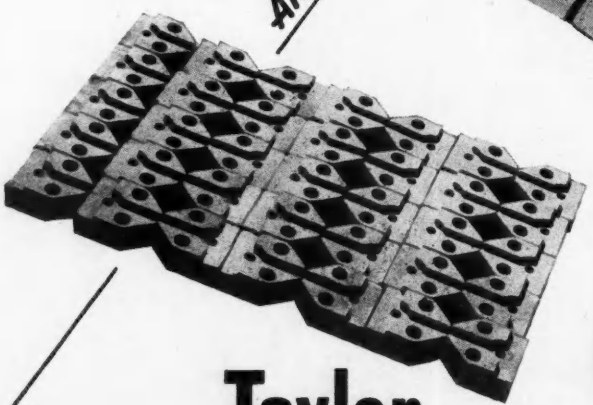
CAMBRIDGE ENGLAND

ONE OF THE PYE GROUP OF COMPANIES

Quick delivery of die-pressed ceramics is now available.....







ANYWHERE · ANYTIME · ON TIME

N

W

E

S

Taylor Tunnicliff & Co., Ltd.

PORCELAIN AND CERAMIC INSULATORS FOR ALL ELECTRICAL PURPOSES

OVERHEAD LINE INSULATORS · SWITCHGEAR INSULATORS · BUSHES AND BUSHINGS · DIE MADE ARTICLES FOR LOW VOLTAGE APPLICATIONS · CERAMICS FOR RADIO FREQUENCIES · REFRACTORIES FOR HEATING APPARATUS · FISH SPINE BEADS ETC.

HEAD OFFICE : EASTWOOD · HANLEY · STAFFS. Stoke on Trent 5272/4

LONDON OFFICE : 125 HIGH HOLBORN · W.C.1. Holborn 1951/2

G.E.C.

Cathode Ray Tubes and Germanium Diodes

Osram

VALVES

New types to meet the requirements of modern television

New types recently added to the range of OSRAM VALVES and G.E.C. cathode ray tubes and germanium diodes, are briefly described here. In addition the table below forms an application guide to the current television range, showing at a glance the most suitable type for use in the various stages of a modern television receiver.

★ **Z309** A B9A based video output pentode designed to provide the increased drive required by modern cathode ray tubes. It has a slope of 15mA/V. and the 12.6V., 0.3A heater is centre-tapped for 6.3V. operation.

★ **Z719** An internally screened R.F. pentode on the B9A base. It may be used for R.F. and I.F. amplification in television receivers, and also as a video amplifier or sync. separator. The slope is 7.4mA/V. and the low anode voltage of 170V. ensures satisfactory operation in transformerless receivers. The heater, rated at 6.3V. 0.3A. is suitable for series or parallel operation. Two cathode connections are provided to reduce R.F. input damping.

★ **N329** A B9A based output pentode with a 16.5V., 0.3A heater for use as a sound or frame time base output valve in transformerless television receivers. The slope is 9mA/V., and an audio output of 4 watts can be obtained with an anode supply of 170V.

★ **U43** A miniature wire-in indirectly heated half wave rectifier suitable for providing E.H.T. from the line time base fly-back pulse or R.F. oscillator. The heater rating is 6.3V. 90mA and the maximum P.I.V. 17kV.

★ **GEX34** A germanium diode developed for use as a sound detector, sound noise limiter and a high level vision detector. It is particularly suitable for driving the sound output stage direct where a sufficiently great R.F. input is available, and undergoes a special functional test during manufacture to ensure satisfactory operation in this application. The GEX34 replaces the GEX44/1 for all purposes.

★ **7201A** A 14" rectangular all-glass cathode ray tube with 70° deflection angle. The screen is aluminised, and the sensibly flat filter glass front which has a transmission factor of 65% obviates the need for a separate viewing filter. The maximum EHT is 14 kV. The heater is rated at 6.3V. 0.3A and is suitable for series or parallel operation.

★ **305 barretter** A 0.3A. barretter for use as a heater current stabiliser in television receivers with series connected heater circuits. It has a voltage range of 40-90V., the current regulation being 5%. The use of a barretter tends to prolong valve and tube life under conditions of fluctuating mains voltage and minimises deterioration of picture quality when the input voltage is abnormally low.

Mixer	R.F. & I.F. amplifier	Video detector	Video amplifier	Sync. separator	Line osc.	Line output	Booster diode	EHT rectifier
B309 X79 Z77 ★ Z719 GEX66	Z77 ★ Z719	★ GEX34 GEX35	★ Z309 ★ Z719 Z77	Z77 ★ Z719	B309 Z77 L77	N339	U329 U309	★ U43
Frame osc.	**Frame amp.**	**Sound amp.**	**Sound output**	**Sound detector. Sound noise limiter**	**Sync. clipper and spot limiter**	**Barretter**	**Power rectifier**	**Cathode ray tube**
B309 ½LN309 L77	★ N329 ½LN309	L77 ½LN309	★ N329 ½LN309	★ GEX34	D77	★ 305	U319	12" 7102A 14" 7201A (rect.)

Write to Osram Valve and Electronics Dept. for full technical details

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2.

The Vital Link . . .

. . . with safety in the hazardous enterprise of the deep sea trawler is its radio and radar equipment upon which safe navigation depends. Thousands of soldered joints contribute to the efficient functioning of this delicate apparatus. One dry or H.R. joint could mean the breakdown of a circuit, the destruction of the vital link, a perilous voyage.

FAULTLESS FLUXING PRESERVES THE VITAL LINK

Dry or H.R. joints are impossible with Superspeed for the flux is always released in exactly the correct proportion. This faultless fluxing action is achieved by the unique STELLATE core which gives six points of rapid solder collapse. At soldering temperature the activated rosin flux is released immediately for effective spreading and wetting. Superspeed is being used more and more in the production of radio and radar equipment where faultless joints are essential.

Superspeed

"WHITE FLASH" ACTIVATED ROSIN-CORED SOLDER

for general electrical, electronic and telecommunication work and all standard uses. A.I.D. and G.P.O. approved. Complies with M.O.S. Specification DTD 599. In all standard tin/lead alloys, 10-22 s.w.g. Also available in a range of coloured cores, indispensable for simple intermediate and final inspection and circuit or operator identification. Samples of Superspeed and the comprehensive Superspeed booklet gladly sent on request. Technical advisers are available for free consultation.

Cored and solid solder rings and solid solder washers supplied to customers' specifications.

MANUFACTURED BY THE **ENTHOVEN** GROUP

Marketed by Enthoven Solders Limited, Enthoven House, 89, Upper Thames Street, London, E.C.4. Tel. Mansion House 4533

Mullard Ferroxcube being extruded into rods for H.F. cores.

MAGNETIC MATERIALS Extensive research and manufacturing facilities have established Mullard as the leading producers of magnetic materials. They were the first, for example, to introduce Ferroxcube, the world's most efficient magnetic ferrite; 'Ticonal' anisotropic permanent magnets, renowned for their high stability and high energy output; and Magnadur, an entirely new type of permanent magnet with the insulating properties of a ceramic.

The wealth of experience gained from these developments is available to all users of magnetic materials through the Mullard advisory service. An enquiry to the address below will put a team of specialised engineers at your disposal.

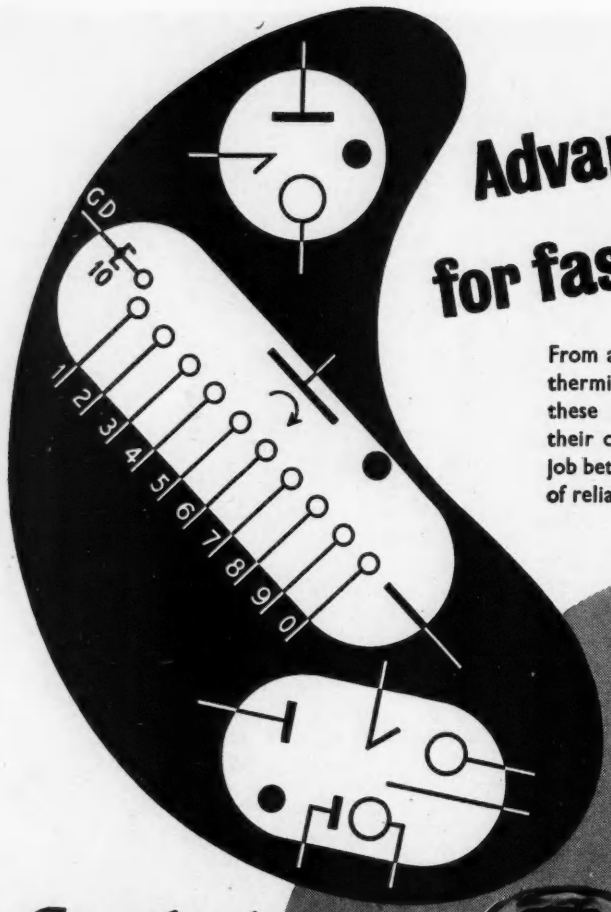
Mullard **Mullard**

'TICONAL' PERMANENT MAGNETS · MAGNADUR (Formerly Ferroxdure) PERMANENT MAGNETS · FERROXCUBE MAGNETIC CORE MATERIAL

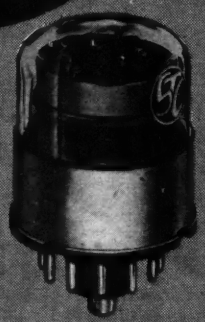
MULLARD LTD., COMPONENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2.

Advanced design for fast triggering

From amongst the wide range of *Standard* thermionic tubes for industrial applications, these three are undoubtedly leaders in their class; designed and built to do the job better... quicker... and to offer a level of reliability that is traditionally ***Standard***.



G1/235Q
Sub-Miniature
Cold-Cathode
Gas-Filled Relay



G10/241E
"Nomotron"
Unidirectional Cold-Cathode Gas Tube Decade Counter

G1/378K
High-Speed Primed-Trigger Cold-Cathode Tube

Standard VALVES for a full life

Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, London, W.C.2

RADIO DIVISION • Oakleigh Road • New Southgate • London • N.11

A Unique General Purpose Fuse by "Belling-Lee"

★ **GREATER CONSISTENCY OF PERFORMANCE**

★ **LOCKED CAPS AND IMPROVED MECHANICAL STRUCTURE**

★ **CLEAN MODERN DESIGN [IN KEEPING WITH] MODERN INSTRUMENT PRACTICE**

★ **CONSIDERABLE PRICE REDUCTION**

NEW technique and streamlined production methods have enabled us to produce a general purpose fuse which electrically has a greatly improved consistency of performance and which mechanically, contains many desirable features. Unless the tube is shattered the caps cannot become loose, and the element is safe even under conditions of extreme vibration and rapid temperature changes, the tube being virtually hermetically sealed.

Despite the many design improvements, we have been able to make considerable price reductions in this range.

"Belling-Lee" L.1055 fuses comply with the dimensional requirements of the last published edition of B.S.646 (B). This is now out of print and under revision. In the meantime, our L.1055 fuses are being made to the modified blowing tests recommended by the appropriate R.E.C.M.F. Standarisation panel.

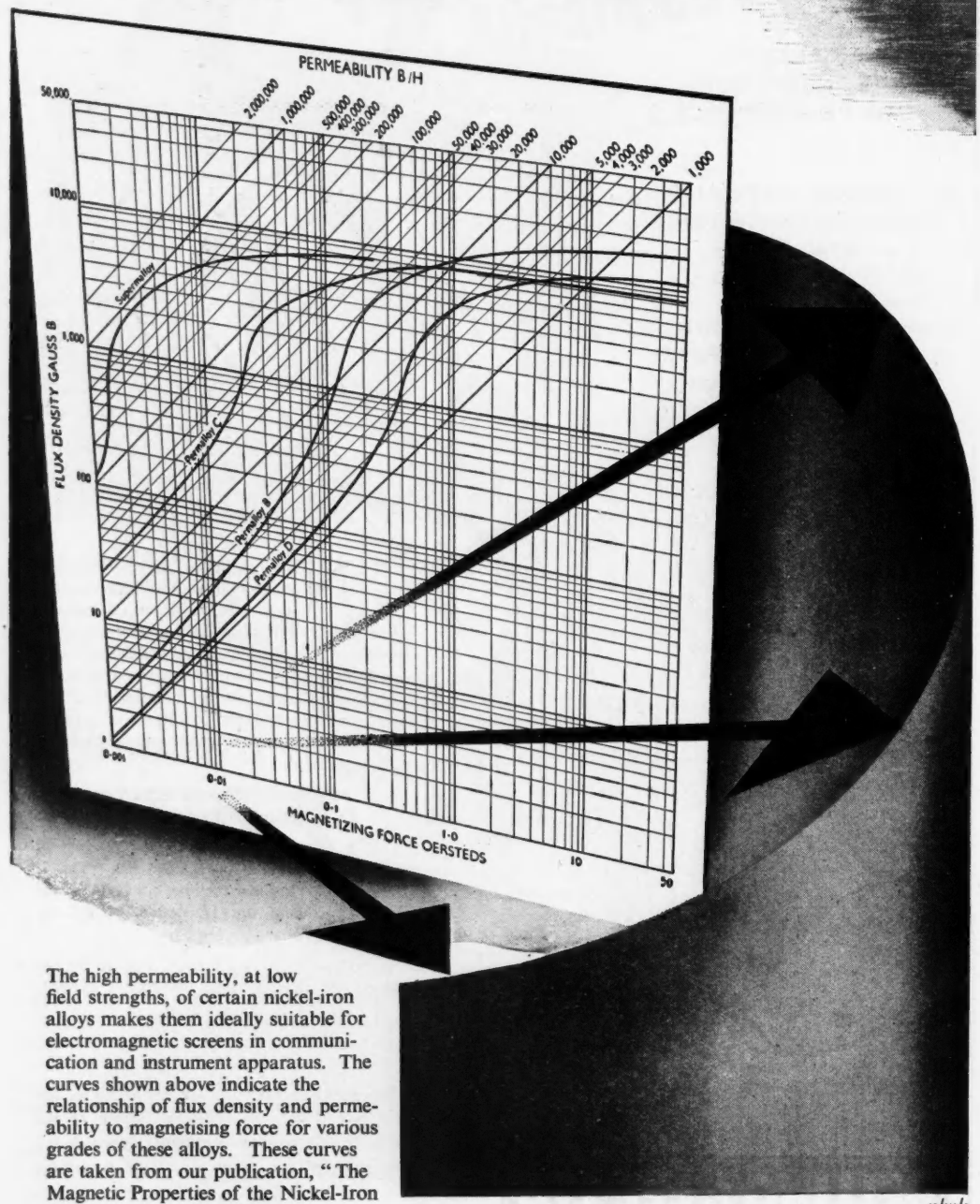
The fuses are made in ratings from 60 mA to 25 amps, but we do not guarantee that ratings above 7½ amps will clear the high prospective currents specified for the lower ratings.

Manufacturers and Technical Organisations on our mailing list will shortly be receiving copies of the "Belling-Lee" 1953 general catalogue, in which full details are given of our range of circuit protection devices.

If you would like to be placed on our list, please write quoting P.365/E.E.

BELLING & LEE LTD
CAMBRIDGE ARTERIAL RD., ENFIELD, MIDDX., ENGLAND

Nickel-Iron Alloys for Magnetic Screens



The high permeability, at low field strengths, of certain nickel-iron alloys makes them ideally suitable for electromagnetic screens in communication and instrument apparatus. The curves shown above indicate the relationship of flux density and permeability to magnetising force for various grades of these alloys. These curves are taken from our publication, "The Magnetic Properties of the Nickel-Iron Alloys". Write for a free copy.

12/N1/6

THE MOND NICKEL COMPANY LTD · SUNDERLAND HOUSE · CURZON ST · LONDON · W1

XEROX

Precision Cathode Ray Tubes

High-speed Recording Tube
Series S6A

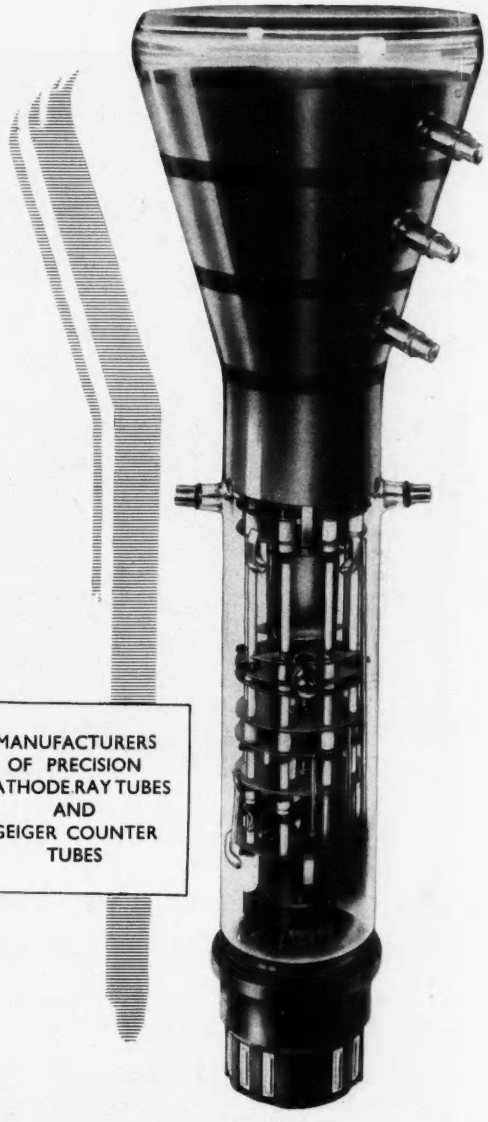
This is a 6 in. Precision Tube with a flat face ground and polished internally and externally. The accurately aligned gun gives freedom from spot aberrations, small trapezium distortion and minimum deflection errors. The tube is rated at a maximum accelerating potential of 12.5 KV and when used with fast blue-sensitive photographic emulsions it is capable of resolving milli-micro-second phenomena. Both X and Y deflector plates are brought out to side arms to give low plate capacity.

20th Century Tubes

Series		S6A
Diameter		6 in.
Overall length (mm.)		480
Heater Volts		6.3
Sensitivity	X	700*
mm./volt x VA_3	Y	1100*
Plate Capacity	X	6
$\mu\mu F$	Y	5
VA_3 max. KV		5
VA_5 max. KV		12.5

* This is reduced by 30 per cent when the ratio of VA_3 to VA_5 is 2 : 5.

Screens
S6AB — BLUE
S6AG — GREEN

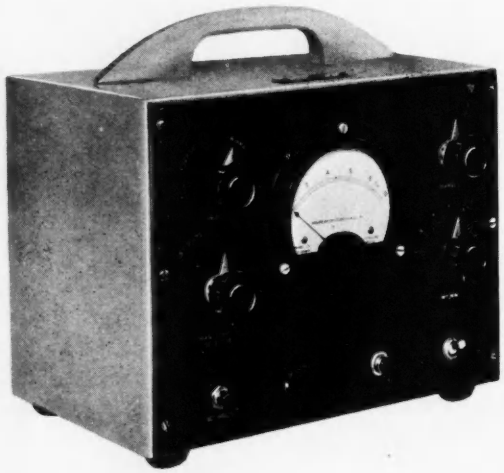


MANUFACTURERS OF PRECISION CATHODE RAY TUBES AND GEIGER COUNTER TUBES

20th Century Electronics Limited

20th CENTURY ELECTRONICS LTD. DUNBAR WORKS, DUNBAR ST., WEST NORWOOD. LONDON, S.E.27
Telephone: GIPsy Hill 2277

A Complete New Range



Low-priced

VACUUM GAUGING EQUIPMENT

THERMOCOUPLE GAUGE
Range up to 2 mm.

PIRANI GAUGE
Up to 1 mm in two ranges.

IONISATION GAUGE
10^{-7} to 10^{-3} in three ranges.

COLD CATHODE GAUGE
10^{-6} to 10^{-3} in two ranges.

Send for Data Sheets Nos. 3 and 3A.

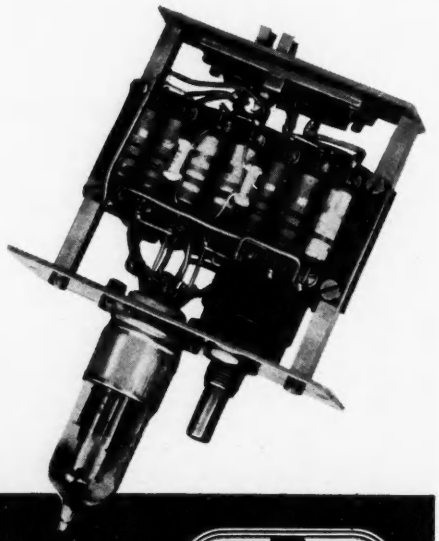
Plug-in

COUNTERS AND SCALERS

for experimental and industrial counting . . .

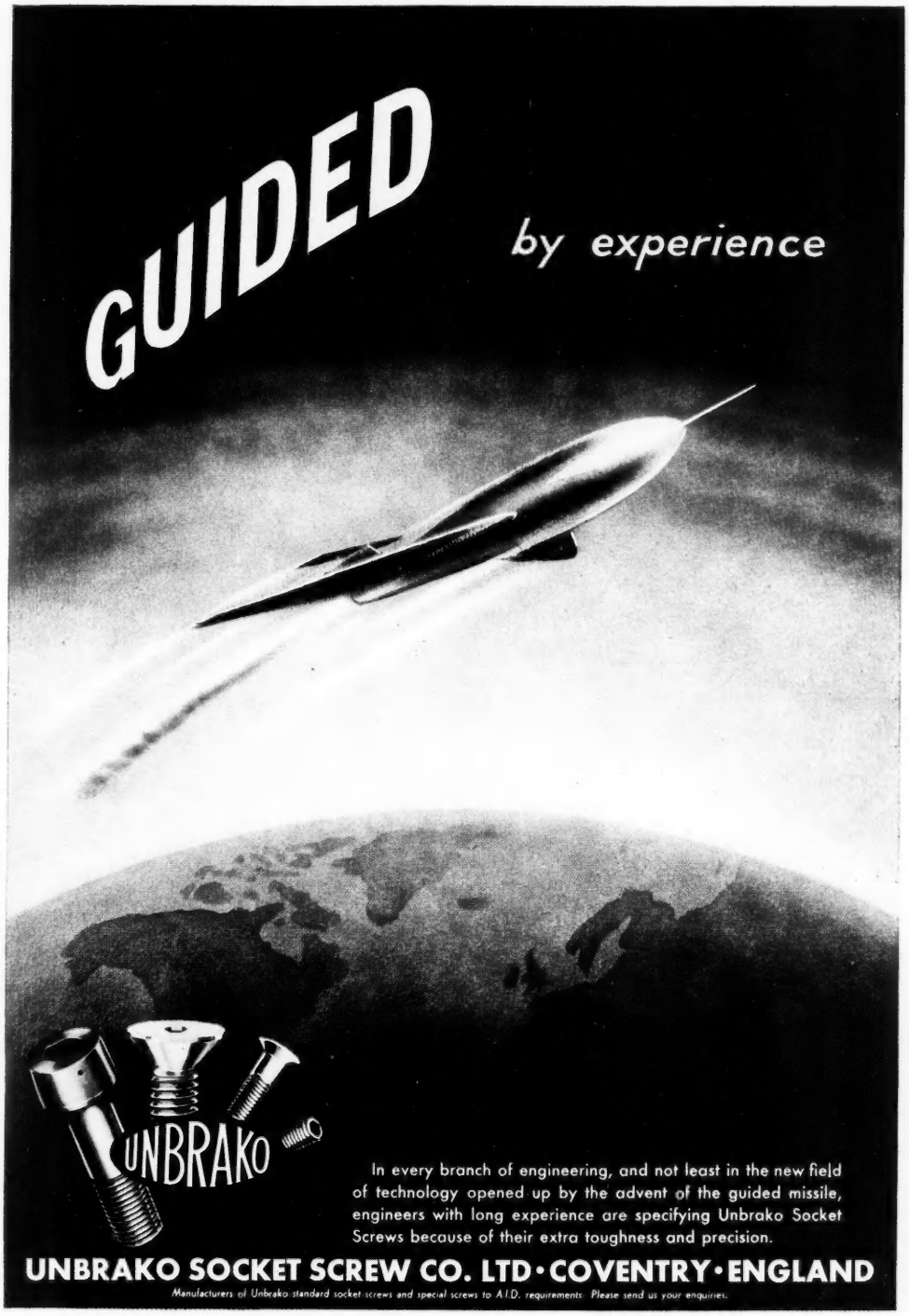
Any combination of counters, input circuit and decatron display units can easily be achieved by plugging in simple interchangeable units. Fault finding and replacement of defective units is considerably simplified.

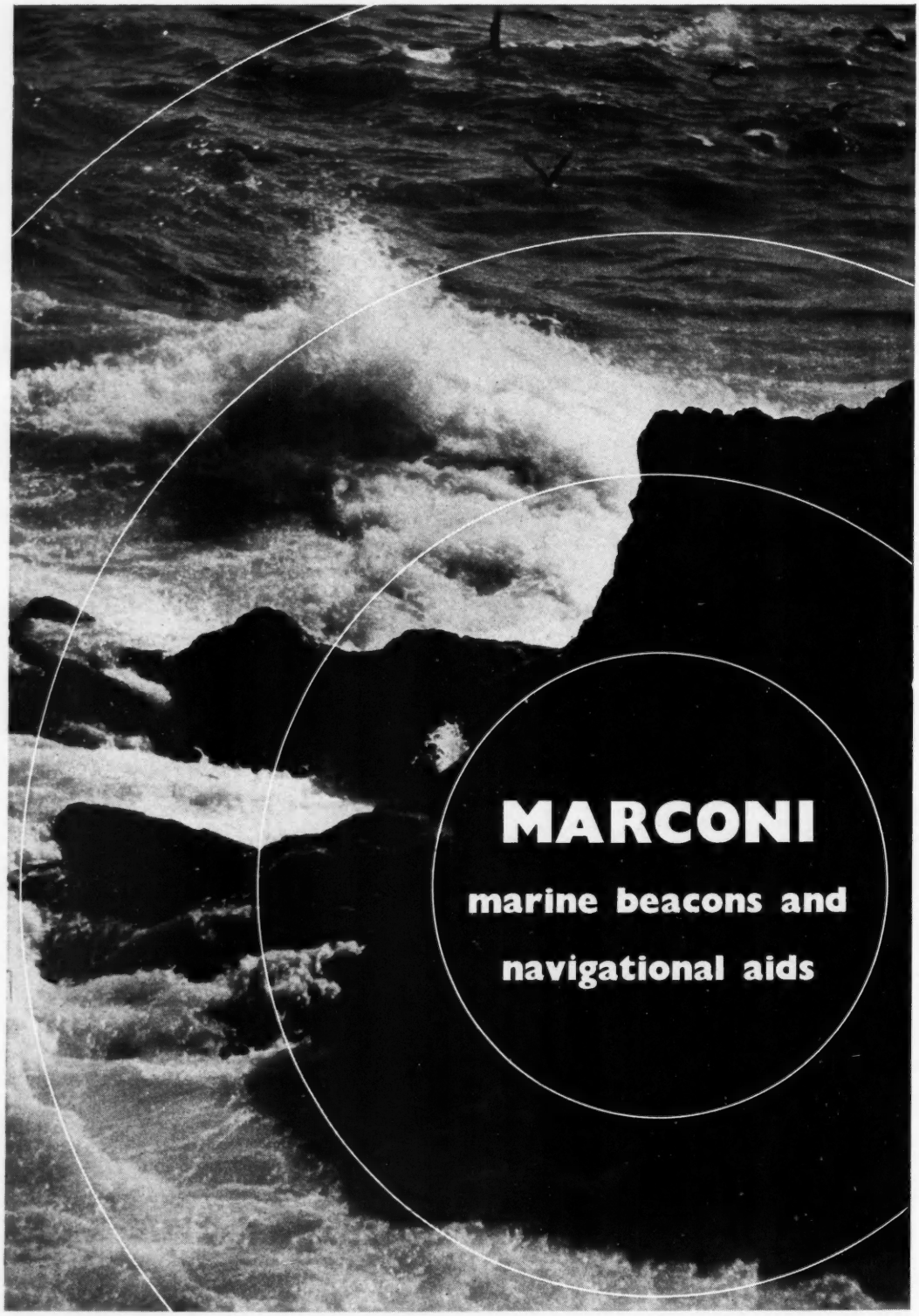
Send for Data Sheet No. 5.



SUNVIC

XU

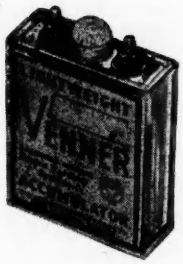

GUIDED
by experience
UNBRAKO
In every branch of engineering, and not least in the new field of technology opened up by the advent of the guided missile, engineers with long experience are specifying Unbrako Socket Screws because of their extra toughness and precision.
UNBRAKO SOCKET SCREW CO. LTD • COVENTRY • ENGLAND
Manufacturers of Unbrako standard socket screws and special screws to A.I.D. requirements. Please send us your enquiries.



MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · CHELMSFORD · ESSEX

OVER
98%
WATT/HOUR EFFICIENCY

and savings up to 4/5 of the size and 5/6 of the weight in comparison with other storage batteries of similar capacities !



The Venner silver-zinc accumulator is ideal when exceptionally high rates of discharge are a necessary requirement.

Weight and space saving are vital in many projects to-day.

Write for Brochure VA/LM.

VENNER Lightweight ACCUMULATORS

VENNER ACCUMULATORS LTD.
Kingston By-Pass, New Malden, Surrey
Telephone : MALden 2442

Electronic Engineering

Incorporating ELECTRONICS, TELEVISION and SHORT WAVE WORLD
Managing Editor, H. G. Foster, M.Sc., M.I.E.E.

Vol. XXV **AUGUST 1953** **No. 306**

Contents

Commentary 313

A Linear Sweep Cathode-Ray Polarograph .. 314
By H. M. Davis and Joyce E. Seaborn

The Characteristics of Some Large-Current Glow-Discharge Tubes 321
By F. A. Benson

A Range of 400c/s and 1600c/s Transductors for Service Use 322
By A. G. Milnes and C. S. Hudson

Sarah 326

An Electronic Trigger Mechanism as a Diagnostic Aid in Electro-Encephalography 327
By M. G. T. Hewlett

A Very Wide Band Dummy Load 330

Simplified Solution of Phase-Shift Networks .. 331
By R. D. Trigg

Encapsulated Reference Resistors 332
By F. L. Valder

Radio Equipment on the British 1953 Everest Expedition 334
By Brig. E. J. H. Moppett and R. W. Lewis

The Electrical Synthesis of Musical Tones (Part 2) 336
By Alan Douglas

A Study of a Second Order Sampling Servo .. 342
By S. R. Cooper

Letters to the Editor 350

Book Reviews 352

Electronic Equipment 354

Notes from the Industry 356

Publications Received 356

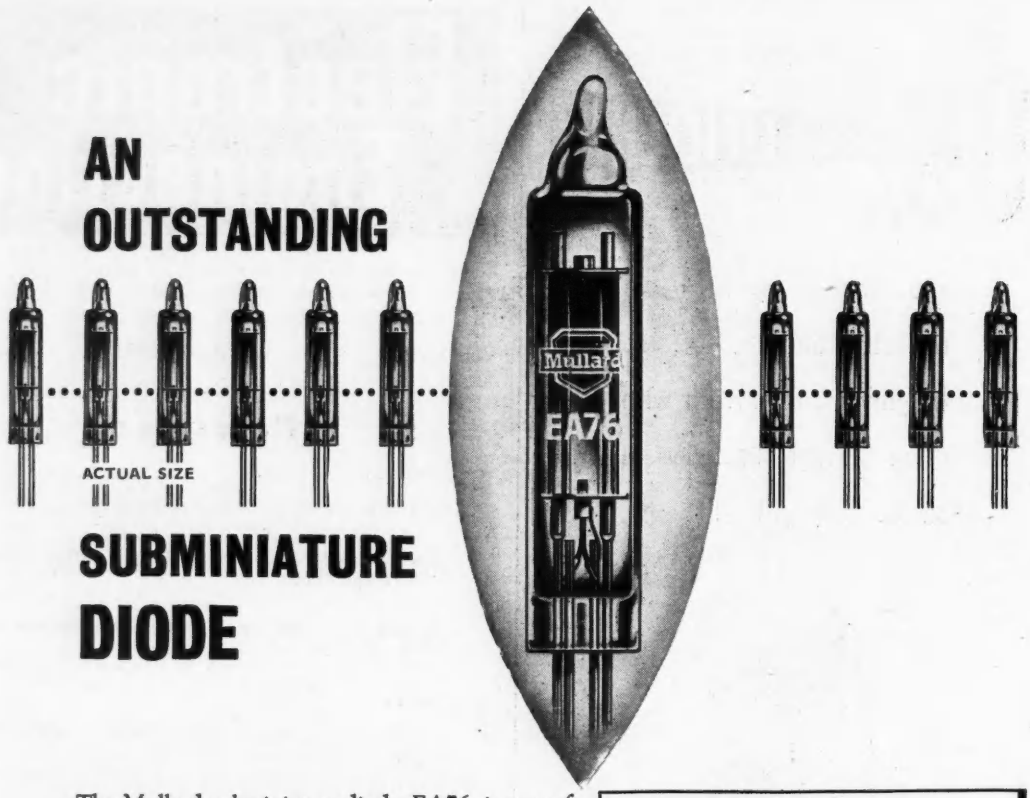
Published Monthly on the last Friday of the preceding month at 28 Essex Street, Strand, London, W.C.2.

Telephone : CENTRAL 6565
Telegrams : ' LECTRONING, ESTRAND, LONDON '

Subscription Rate:
(Home or Abroad) Post Paid 12 months 26s. or $3.75 (U.S.)

Classified Advertisements, Page 1
Index to ADVERTISERS, 80

AN OUTSTANDING SUBMINIATURE DIODE



The Mullard subminiature diode, EA76, is one of the smallest and most efficient thermionic valves of its kind in the world.

A special feature of this valve is that despite its extremely small size (5mm. diameter), it operates efficiently under similar ambient temperature conditions to those governing normal miniature and subminiature valves.

As a result, the EA76 may be used in almost every communications, radar and military equipment where savings in space are required.

The EA76 is now freely available, and designers who require full particulars of performance and price are invited to apply to the address below.

PRINCIPAL CHARACTERISTICS

HEATER		
V_h	6.3	V
I_h	0.15	A
CAPACITANCES (Measured without external shield)		
c_{a-k}	2.8	μμF
c_{a-h}	0.5	μμF
c_{h-k}	2.0	μμF
CHARACTERISTICS		
D.C. voltage drop (I =18mA)	3.1	V
LIMITING VALUES		
P.I.V. max.	420	V
V_a max.	150	V
I_a max.	9.0	mA
$i_{a(pk)}$ max.	54	mA
* $v_{h-k(pk)}$ max.	330	V

* Heater negative with respect to cathode.

BASE
B5B (5 mm. subminiature)

GOVERNMENT PREFERRED TYPE NUMBER
CV469

Mullard

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2
M.V.T.140

Electronic Engineering

Vol. XXV AUGUST 1953 No. 306

Commentary

IT has become increasingly obvious ever since the BBC first announced its Five Year Plan for television in this country that a single network could not be expected to satisfy all the people all the time, and that sooner or later plans to provide an alternative programme would have to be evolved. As television extended northwards and westwards from London the different tastes and habits of the various sections of the population made this need more apparent than ever and there is no doubt that sponsored television has contributed much to the public interest in these matters.

But such demands cannot be satisfied overnight and many problems have to be solved. Apart from such difficulties as Government restriction on capital expenditure, one of the foremost is the availability of suitable television channels in the rapidly overcrowding wavebands.

There have been several Government statements recently on the future both of television and sound broadcasting but no firm decision could be taken until the technical aspects were first settled.

A Television Advisory Committee was therefore set up in October of last year under the chairmanship of Admiral Sir Charles Daniel "to advise the Postmaster General on the development of television and sound broadcasting at frequencies above 30Mc/s and related matters, including competitive television services and television for public showing in cinemas and elsewhere."

These are very wide terms of reference, and to advise the P.M.G. on all these aspects would take an appreciable time; consequently the first report of the Television Advisory Committee which has just been published deals only with the development of television in the home both by the BBC and competitive organizations, leaving sound broadcasting and cinema television to be discussed in later reports.

In the range of frequencies for television and sound broadcasting surveyed by the Committee—namely from 30Mc/s to 3 000Mc/s—there are, in fact, no more than three V.H.F. and two U.H.F. bands which have been assigned by international agreement for this purpose.

Designated bands I to V, their frequency ranges are as follows:

Band I	41— 68Mc/s	V.H.F.
Band II	87·5—100Mc/s	V.H.F.
Band III	174—216Mc/s	V.H.F.
Band IV	470—585Mc/s	U.H.F.
Band V	610—960Mc/s	U.H.F.

A technical subcommittee under Dr. W. G. Radley, was brought into being to examine the rather weighty technical considerations and it is largely on the work of this subcommittee that this report is based.

The report is therefore technical in nature and it must be left for a higher authority to shape the future of television by the BBC and the competitive organizations for the report does little more than disclose the present state of affairs.

Dealing with the bands in turn the Committee finds that all the available channels in Band I will be required to complete the BBC's present network some details of which were outlined recently by Sir Ian Jacob, the Director-General of the BBC. As is known, this network will comprise the existing five high power stations—including a new transmitter for the London area—and the proposed five medium power stations which have been held up on account of capital expenditure restrictions.

These ten stations will be supplemented by low power stations at the Isle of Man and the Channel Islands and it has been put forward that a further six low power stations will be required for those "pockets" not served by the higher powered stations. Thus the network will comprise some eighteen stations all but the six low power stations being accommodated in Band I.

This network forms the very foundation of British television broadcasting and it must be agreed almost as a matter of national policy that this network should be completed as soon as possible, leaving the second or alternative BBC network and the claims of the competitive organizations to be met from the remaining bands.

Band II is regarded as too narrow to be of much use for television but it will come into prominence in the future for the Committee suggests that this band be reserved for sound broadcasting. This will do much to alleviate the unsatisfactory reception now existing on the medium and long wavebands.

Band III would appear to be the most desirable for television from several points of view but it is largely occupied by the fixed and mobile services and by the highly important radio navigational aids, and none of these can be transferred to another part of the frequency spectrum without incurring considerable cost.

One of the principal advantages of Band III is the much greater service area it can provide—it is estimated that at least twice as many transmitters would be required to provide the same coverage by bands IV and V—but no less important is the fact that television development plans in many European countries are based on the use of this band and it is argued, with some justification, that if the British radio industry is to compete successfully in the export markets there must be a thriving home market for television transmitters and receivers in this band.

But the present situation is that there are only two channels which can be made immediately available and these would allow only a part of the alternaive network the BBC proposes. The competitive organizations and the remaining section of the BBC alternative network would thus be transferred to Bands IV and V.

Here there are however no less than 93 channels available on a basis of 5Mc/s bandwidth, fifty of which could be made available immediately, but the report emphasizes that costs both at the transmitting and receiving ends would be high.

It is perhaps fortunate as far as the Television Advisory Committee is concerned that its terms of reference do not compel it to settle these controversial problems.

As we see it, there can be no argument against the claims of the BBC to complete the present network; but for the rest it appears to be a straight fight between the alternative network and the competitive organizations for the available channels in Band III. Whoever obtains these channels will gain on the score of wider service area and reduced operating costs, but the viewer, unless he restricts his viewing to the present network, faces additional costs all round—a considerably more expensive receiver than at present and a veritable forest of aerials from his roof.

A Linear Sweep
CATHODE-RAY POLAROGRAPH

By H. M. Davis*, B.Sc., A.R.I.C., and Joyce E. Seaborn*, B.Sc.

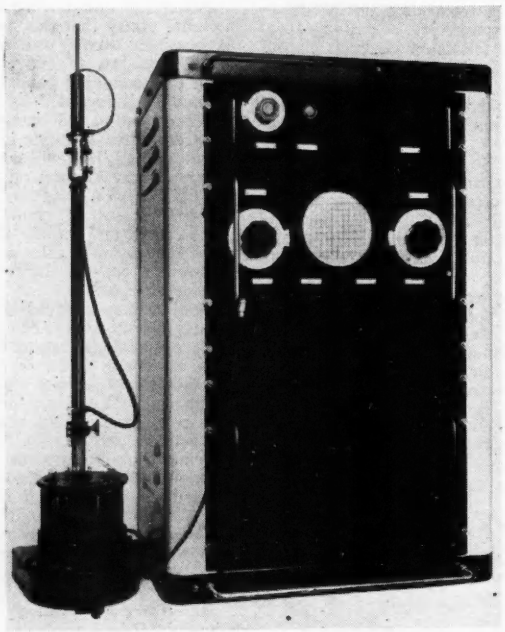
The circuit of a linear sweep cathode-ray polarograph, which has been designed primarily for use by operators with little knowledge of electronic equipment, is presented.
The sensitivity of the instrument is considerably greater than that of instruments hitherto commercially available, and it offers advantages both in rapidity of operation and in the resolution obtained between adjacent steps. A number of refinements, not previously described in instruments of this type, have been incorporated. These include compensation for the capacitive current flowing in the cell and means for the presentation of a derivative trace.

THERE is a considerable field of application for electronics in the chemical laboratory, particularly in instruments for the measurement of small voltages and currents. One such instrument is the polarograph, which is used to determine the concentration of reducible ions in a solution, by measurement of the current that flows when the ions are electrolytically reduced.

Only a brief description of the polarographic method of analysis is given here, full details may be found in any of the standard works on the subject, such as that by Kolthoff and Lingane[1]. The technique consists essentially of electrolysing a solution of the material to be analysed, in a cell having a mercury anode and a dropping mercury cathode. The voltage applied to the cell is varied by means of a potentiometer, usually over the range 0-2 volts, and the cell current is recorded on a sensitive galvanometer.

There are several reasons for the choice of a dropping mercury cathode, one of which is that, if effects due to contamination by the reduced ions are to be eliminated, the cathode surface must be continually renewed. This is achieved quite simply in practice by causing mercury to flow from a reservoir of adjustable height, through a fine glass capillary which has one end immersed in the solution. The drops which form at the immersed end fall through the solution after a life of a few seconds and are collected in the anode pool. Electrical connexions are made to the mercury in the reservoir and to the anodic pool in the bottom of the cell by means of platinum tipped wires.

The current through the galvanometer fluctuates continually with the growth and fall of each drop at the cathode and it is therefore necessary to use a heavily damped instrument of long period to ensure that the mean cell current is indicated.



The complete equipment.

The substance to be analysed is dissolved in a solution containing an excess of an electrolyte, such as potassium chloride, which is not reduced within the range of cell voltage normally used in analysis. Under these conditions, as the voltage across the cell is increased from zero, the current is at first very small, but when the voltage reaches the value at which one of the ionic species present in the solution is reduced, the current rises sharply with voltage until it reaches a limit imposed by the rate of diffusion of the ions towards the cathode. If other reducible ionic species are present, similar step-wise increases in the current occur as their reduction potentials are attained.

The potential at the mid-point of each step, where the current is equal to one-half of its limiting value, is known as the "half-wave potential" and it is characteristic of the ionic species being reduced. The total change of current is proportional to the concentration of the ionic species in the solution. Both these quantities are obtained from the curve of mean cell current against voltage, which may be plotted either manually or automatically. A typical polarogram is shown in Fig. 1. The time taken to produce the curve with a photographic polarograph is about ten minutes.

The response of the galvanometer to the current change at each step must be sufficiently fast relative to the rate of change of cell voltage, to avoid serious distortion of the curve. This sets a limit to the damping which can be imposed on the instrument and it is usually necessary to adopt a compromise value, which does not always reduce the drop wave sufficiently at high instrumental sensitivities, for easy and accurate measurement of step height to be possible.

The Linear Sweep Cathode-Ray Polarograph

An alternative method of polarography due to Randles[2,3,4] is well suited to electronic treatment and offers

* *Ministry of Supply, Chemical Inspectorate, Kidbrooke.*

advantages in sensitivity, speed and resolution between adjacent steps. In this system, a linear potential sweep is developed across the cell once in the life of each drop, instead of being spread over the lives of many drops, as in instruments of the type described above. A resistor is connected in series with the cell and the voltage appearing across it, which is a measure of the cell current, is amplified by a D.C. differential amplifier and applied to the Y deflexion plates of a long after-glow cathode-ray tube. The voltage appearing across the cell is also amplified and applied to the X deflexion plates of the tube, so that the resulting display is a graph of cell current as a function of cell voltage. A special circuit is used to maintain a constant rate of change of potential across the cell, irrespective of the ohmic drop occurring in the series resistor.

It is necessary to delay the onset of the potential sweep until late in the life of each drop, when the rate of change of drop surface is small, since any major change of surface would cause undesired variations in the cell current. This delay period is made constant for every drop by locking the sweep generator in synchronism with the dropping

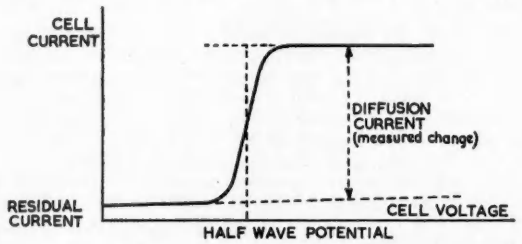


Fig. 1. Trace obtained with conventional polarograph when examining solutions containing cations due to one element

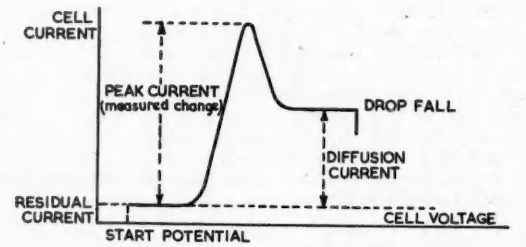


Fig. 2. Trace obtained on linear sweep C.R. polarograph when examining a solution containing cations due to one element

electrode, thus ensuring a reproducible trace.

The effect of applying a rapid potential sweep is to produce a current waveform which exhibits a peak, because of the rapid stripping of ions from the solution immediately surrounding the drop when their reduction potential is attained. As the potential continues to rise, the current falls below the peak value until it reaches a level governed by the rate at which ions can diffuse through the solution towards the drop (Fig. 2). It was shown by Randles[3,4] both theoretically and experimentally, that the rise in current occurring at the peak is linearly related to the concentration of the ionic species undergoing reduction and it is this rise which is measured in analysis.

It is an advantage of the linear sweep polarograph that, since the current rises to a maximum value which is always greater than the diffusion current level, it is inherently more sensitive than instruments of the conventional type.

Instruments have been designed, operating on this principle, by Randles and Airey[3,4] by Weidmann[5], and by Snowden and Page[6].

The instrument constructed by Randles and Airey, in the laboratories of the Chemical Inspectorate, was successful in that it clearly demonstrated the analytical value of the method, but because of the complexity of its controls, it was unsuitable for use by operators without considerable knowledge of electronic equipment.

The apparatus has therefore been completely redesigned with the requirements imposed by routine analytical use in mind and, in particular, the panel controls requiring manipulation by the operator have been reduced to the minimum number consistent with full flexibility. Some of the quantities which were variable in the earlier instrument have been fixed, where this could be done without impairing performance. These are, the rate of change of cell potential, which has been set at 0·3 volt per second; the delay period before the onset of the sweep, which has been set at five seconds; and the voltage gain factors of the X and Y deflexion amplifiers. In addition, the overall sensitivity of the instrument has been increased, and a method has been devised for the neutralization of effects due to the cell capacitance[7]. Provision has also been made for an alternative trace, closely corresponding to the time derivative of the cell current waveform, to be displayed on the cathode-ray tube. This trace is more sharply peaked than the parent waveform, and the resolution of the instrument is accordingly increased. Under favourable conditions, peaks corresponding to reductions occurring at potentials only 30mV apart may readily be separated.

Instruments based on this design have been in use in the Chemical Inspectorate for the past three years and, although developments have from time to time been carried out, no basic modifications have been found necessary.

Description of Circuits

Details of the circuits used (Figs. 4, 5 and 6) are now described.

Sweep Generator and Compensation Circuits

These circuits are the most important in the apparatus. They are required:

(1) To generate a potential waveform which
  (a) has a steady value during a fixed period commencing with the start of growth of each drop;
  (b) thereafter changes linearly with time;
  (c) returns to the initial steady state at the fall of each drop.
(2) To reproduce this potential waveform at the cell anode, irrespective of the ohmic drop occurring in the cell series resistor.
(3) To compensate as far as possible for effects arising from the capacitive nature of the cell impedance.

The circuits performing these three functions are as follows.

1. *Generation of the potential sweep waveform* ($V_1V_2V_7V_8$)

The timing of the sweep is accomplished by a normally free running multivibrator (V_1V_2) having metastable states lasting for five and two seconds. One valve of the pair (V_2) is, however, a pentode and the synchronizing pulse derived from the fall of the drop is applied to its suppressor grid by means of C_5 and R_7, so as to drive this grid negative. When this happens, anode current in V_2 is cut off, the grid of V_1 is driven positive and the potential of its anode falls, thereby maintaining V_2 cut off. This condition corresponds to the quiescent period of the sweep generator and continues until the potential of the grid of V_2 has risen sufficiently for the valve again to conduct. By this time the negative going pulse applied to the suppressor grid of V_2 has decayed to zero and the anode circuit of this valve can again pass current. Cumulative action follows and V_2 is then in full current and V_1 is cut off. The voltage sweep, which is controlled by the multivibrator, then starts and is continued until the next pulse is received at the suppressor grid of V_2, when the cycle repeats. Provided that

a sufficiently high value of cell series resistor is used, no action is required by the operator to establish synchronization, other than to make the dropping time of the mercury cathode slightly less than the total period of the multivibrator, i.e. seven seconds. If, however, due to incorrect conditions, no synchronizing pulse is applied to V_2, the sweep is always terminated at the end of the normal period of the multivibrator.

The potential sweep is generated at a high level by means of a circuit of the bootstrap type. V_{8a}, which is controlled

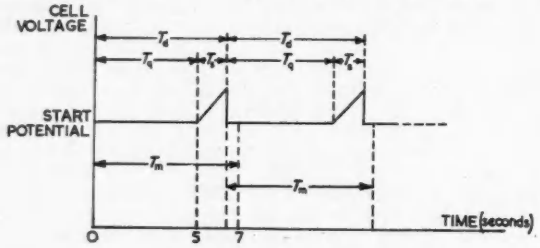


Fig. 3. The voltage waveform at the cell anode

T_d = drop time, T_q = quiescent period, T_s = duration of linear sweep, T_m = normal period of multivibrator.

by the multivibrator, acts as a switch across the timing capacitor C_{10} and allows the sweep to start when its grid is driven negative. The cathode-follower V_{8b} produces a nearly linear rise in potential across C_{10}, by feedback action, and the output of the generator is applied to the network R_{25}-R_{29}. The voltage applied by this network to the grid of V_9 consists of a steady voltage, which may be varied by means of R_{29}, on which is superimposed, late in the life of each drop, a component rising linearly with time. The rate of change of this latter component is approximately 0·3V/sec and is constant for all settings of R_{29} (Fig. 3).

2. *Compensation for ohmic drop in the cell series resistor* (V_9-V_{12})

The form of compensation circuit described by Randles and Airey is efficient, but suffers from the disadvantage that both the sweep generator and the source defining the sweep start potential must be floating with respect to earth

The circuit arrangement used in the authors' instrument[7] was selected as the result of experiment with a number of different designs, aimed at avoiding the difficulty referred to above.

V_9 and V_{10} together serve as a comparator stage. The potential appearing at the slider of R_{29} is applied to the control grid of V_9 and that appearing at the cell anode is applied to the grid of V_{10}.

If, due to an increase in cell current, the potential of the control grid of V_{10} tends to fall relative to that of the control grid of V_9, the effect is that current in the common cathode resistor R_{33} is decreased, with a consequent fall in potential of the anode of V_9. This change increases the voltage at the anode of V_{11a} and hence the voltages at the cathode of V_{12} and at the cell anode, i.e. the action is such as to maintain a constant voltage difference between the cell anode and the slider of the potentiometer R_{29}. The potential existing across the cell during the period before the sweep starts, can thus be controlled by the potentiometer through the intermediary of the compensation circuit.

The basic voltage relation between the cell anode and the slider of the potentiometer may be varied over a small range by adjustment of R_{30}, while retaining satisfactory operation of the amplifier. In the circuit described, R_{30} is adjusted so that with the slider of R_{29} at its minimum potential, the cathode of V_{12} is 0·5V negative with respect to earth, i.e. the electrode that is normally the cell anode is negative relative to the earthed cell cathode. This step is taken to produce the required range of sweep start potentials (+0·5V to −2·0V, European Sign Convention), on varying R_{29}.

It should be noted that, if the use of start potentials between 0 and +0·5V is not contemplated, the performance of the compensation amplifier may be somewhat improved by setting R_{30} so that the cathode of V_{12} is at zero potential under the conditions stated above.

With the circuit as described the feedback has the effect of reducing the voltage drop at the cell terminals, due to current flow in the series resistor, to about one two-hundredth of what it would be in the absence of the compensation. It follows that a variable series resistor (S_1) may be used to control the overall sensitivity of the instrument without materially affecting the voltage existing across the cell.

Since with the highest value of series resistor a current change of one millimicroamp is easily detected, it is desirable that the grid currents of all the valves whose input grids are connected to the cell, should be both small and stable under the conditions of operation. For this reason, the valves V_9 and V_{10} are of the EF37A type which have the described characteristics, particularly when the anodes, screens and heaters are operated at reduced ratings, as is the case in the present design. A similar reason applies to the choice of this valve type for the input stages of the X and Y amplifiers.

It is clearly desirable that the amplifier should be free of any appreciable drift in the period likely to be required for the analysis of a solution. The most important source of drift in an amplifier of this type, assuming reasonably well stabilized H.T. supplies, is variation in the operating temperature of the cathode of the input valves, due to changes in the heater supply voltage. This has been minimized in the present instrument by supplying the heaters of V_9 and V_{10} in series from the main stabilized power supply, and the drift rate of the output voltage does not exceed one millivolt per hour after an initial warming up period of one hour.

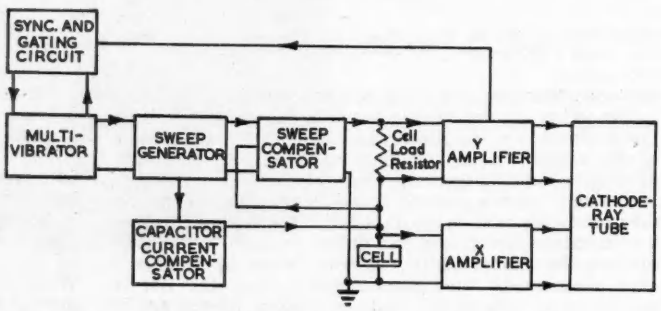


Fig. 4. Block diagram of complete equipment

3. *Compensation for the effect of cell capacitance*

Very approximately, the polarographic cell may be regarded as equivalent to a high resistance in parallel with a capacitance of about one microfarad. It will be seen that when the potential sweep is applied, an almost constant current will flow into the capacitive part of the cell impedance, governed by the relation $i = C\,dv/dt$ (with the usual notation). When high values of cell series resistor are in use, in order to achieve great sensitivity, this current causes

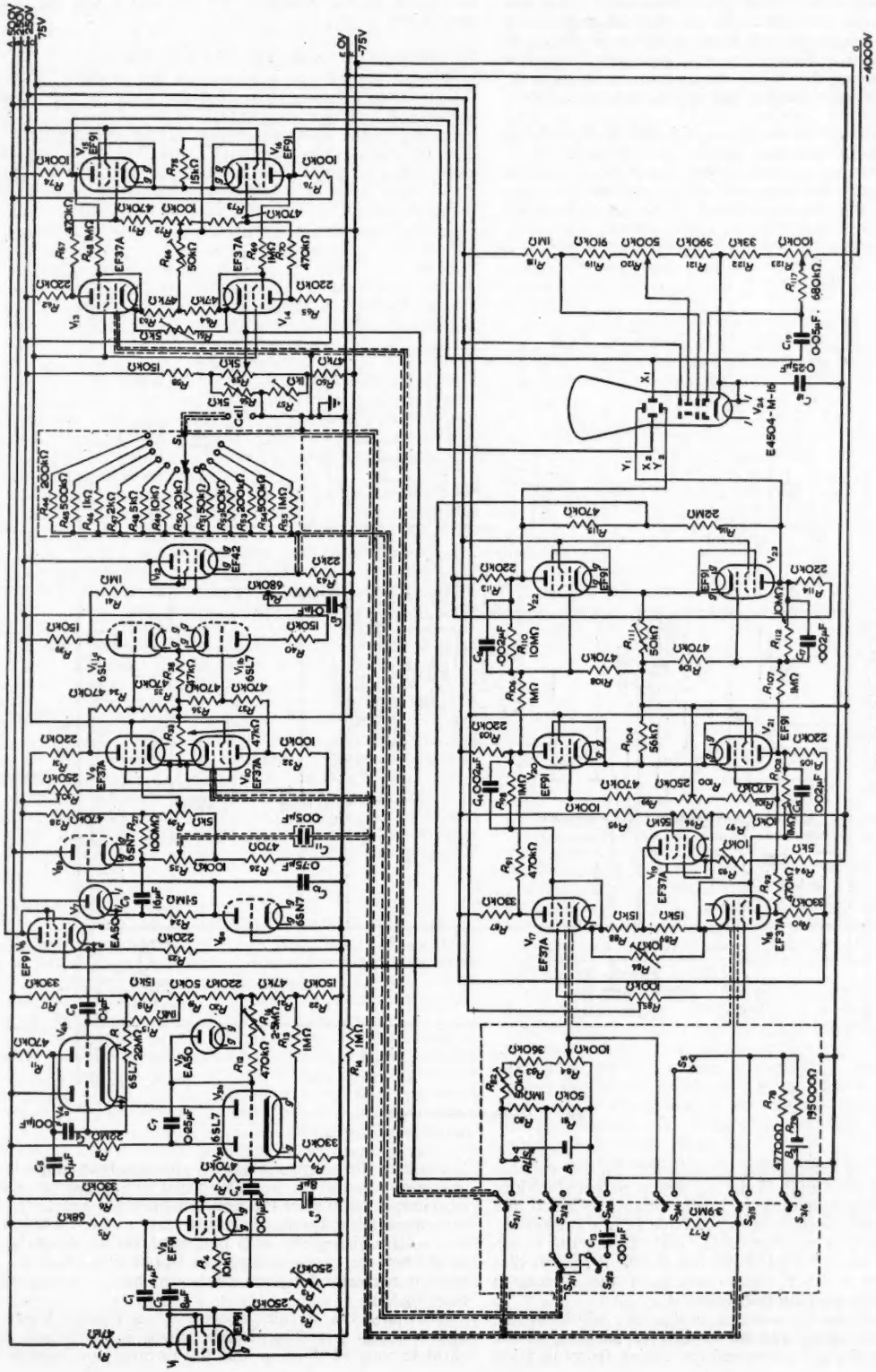


Fig. 5. Measuring circuit

a voltage step to be injected into the Y amplifier of sufficient magnitude to deflect the cathode-ray tube spot from the screen. For example, in the apparatus now described, the maximum cell load resistance is 1MΩ and dv/dt = 0·3V/sec. Hence, the voltage injected into the Y amplifier during the sweep may be as much as 0·3V, while the input required for full screen deflexion is only about 30mV.

The method used to overcome this effect depends on the injection of a constant current into the cell circuit during the sweep period, of sufficient magnitude to produce the required rate of change of voltage across the capacitive part of the cell impedance[7]. This may be readily accomplished by connecting a capacitor C_{11} of suitable value between the anode of the cell and a potential divider in the cathode circuit of V_{3b}. In the circuit described, the rate of change of voltage at the cathode of V_{3b} is 60V/sec, i.e., 200 times that applied to the cell, during the sweep period. With the cell capacitance about 1μF it follows that C_{11} should be 0·005μF. Fine setting of the current is accomplished by varying the control R_{25}.

The method has the advantage that the whole of the available shift voltage can be applied to backing off the voltage across the cell series resistor arising from diffusion current flow in the cell, and to measurement of the magnitude of peaks occurring on the trace due to ionic deposition.

Synchronization and Paralysis Circuits (V_3-V_6)

When a mercury drop falls from the capillary, a sharp fall in current occurs (Fig. 2), from which is derived the pulse used to trigger the multivibrator to the state corresponding to the quiescent period of the sweep generator. The synchronization circuit (V_4 and V_6) producing this pulse must be sufficiently sensitive to respond to a very small input, such as is received when strong solutions are being investigated and the cell series resistor is low.

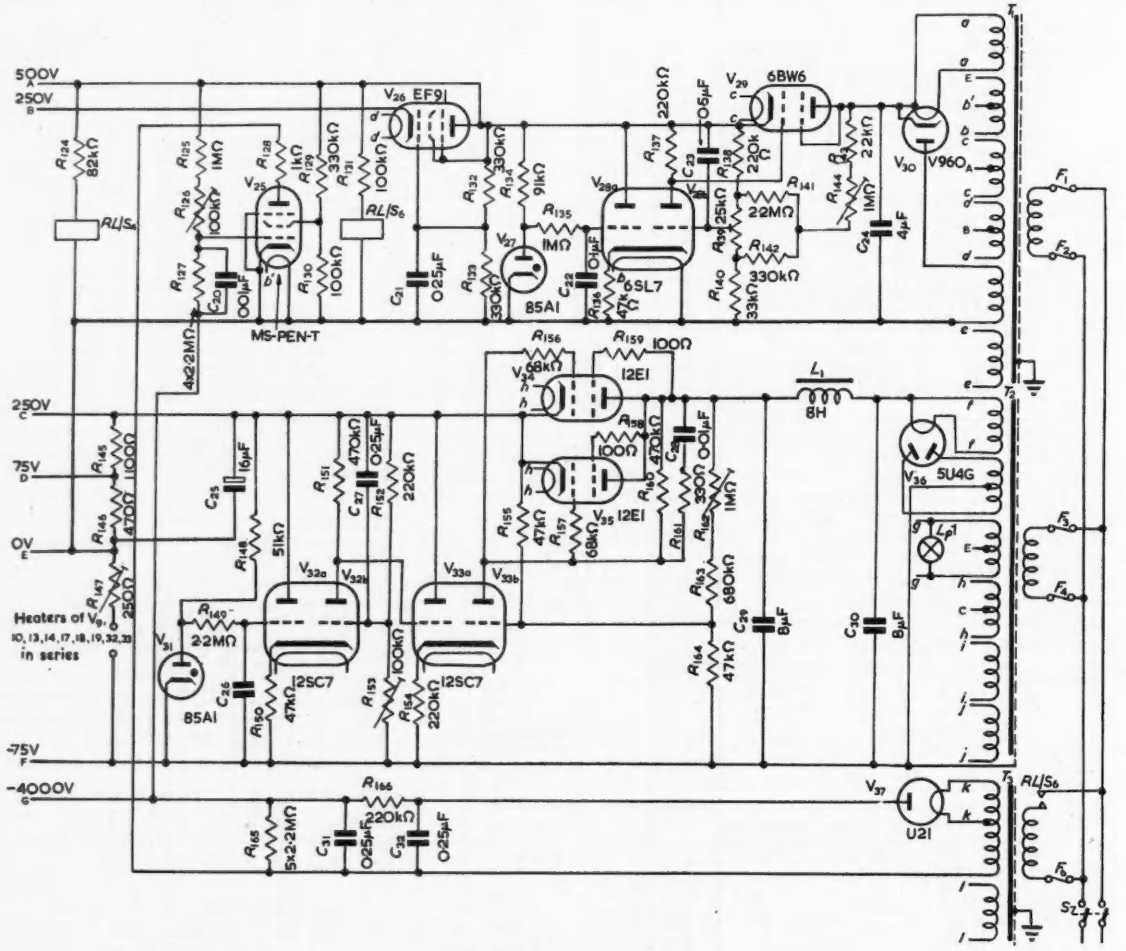


Fig. 6. Stabilized power supplies

Because of this high sensitivity, the synchronizing circuit may also respond to the fairly rapid fall in current occurring immediately after the peak on the trace and terminate the sweep prematurely. For this reason, the operation of the synchronizing circuit is paralysed for a period beginning when the sweep commences and ending when the cell current becomes diffusion controlled and is hence stable (see Fig. 2).

The paralysis circuit[8] consists of a double triode V_3 and a diode V_5. The double triode is connected as a cathode-coupled flip-flop and the normally-on section V_{3b}

forms part of the cathode circuit of the synchronization valve V_4. At the start of the sweep V_5 is switched to the unstable condition with V_{3b} cut off, rendering the synchronization circuit inoperative. After a period determined by the time-constant of its grid circuit, V_{3b} again conducts and turns on V_4. A positive pulse of sufficient amplitude at the grid of V_{4b} will then trigger V_4, which is also connected as a cathode-coupled flip-flop, and cause a negative pulse of fixed amplitude to be delivered to the suppressor circuit of V_2, thus resetting the multivibrator.

The period of paralysis is controlled by R_{16} and the threshold level for triggering V_4 is varied by means of R_{19}.

X Amplifier (V_{13}-V_{16})

This part of the circuit amplifies the voltages appearing across the cell to a sufficiently high level for use on the X deflector plates of the cathode-ray tube. The voltage gain of the amplifier is controlled by negative feedback and is adjusted by means of R_{61} so that a deflexion of 1cm in the X direction corresponds to an input voltage of 0·05V.

One of the input grids is connected to the cell anode, the other to a shift network R_{56}-R_{60}. The balance control R_{72} in the amplifier is so adjusted that, when the potentials of the two input grids are the same, the cathode-ray tube spot lies on a particular line near the left-hand side of the graticule. This line is thereafter taken as the reference for start potential settings.

Any required start potential for the sweep may then be selected by applying a known potential to the input grid of V_{14} from the network R_{56}-R_{60} and adjusting R_{29} until the spot returns to the reference line. The control R_{59} is calibrated over a range of $+2{\cdot}0$V to $-0{\cdot}5$V relative to earth. The signs of the voltages are reversed on the control in the authors' instrument, so as to conform with the European Sign Convention.

The start potential is determined by this procedure with sufficient accuracy for all normal requirements. In the event of greater accuracy being required for a special purpose the quiescent cell potential may be found by connecting a suitable high impedance meter directly to the cell terminals. The potential at which any peak occurs may be calculated from a knowledge of the start potential and the displacement of the peak in the X direction.

All power supplies for the amplifier, with the exception of that for the heaters of the output stage, are stabilized and the drift rate referred to the input does not exceed one millivolt per hour after an initial warming up period of one hour.

Y Amplifier (V_{17}-V_{23})

The voltage appearing across the cell series resistor is presented to a conventional three-stage balanced amplifier to which negative feedback is applied in two loops. The high frequency response of the amplifier is restricted by means of $C_{14}C_{15}$ and $C_{16}C_{17}$ in order to remove the necessity for screening the cell from A.C. pick up.

It is necessary that the discrimination of the amplifier against in-phase inputs should be sufficiently high to ensure that, with the cell circuit open, the trace does not deviate appreciably from the horizontal at any start potential setting. This implies that the input valves must be carefully matched, but provision is made in the design for eliminating effects due to small variations in valve characteristics. The method of matching is described later.

The adjustment of the amplifier is carried out as follows. After setting the mean anode potentials of V_{17} and V_{18} to 75V by means of R_{93}, the gain of the amplifier is adjusted to 10 000 using R_{86}. The calibrated shift control R_{84} is then set to 50mV and the trace, with zero input and the sensitivity switch S_1 set to its minimum value, is adjusted to the centre line of the graticule by means of R_{100}.

The trace is then examined at different start potential settings. If it has a slope, the differential screen control R_{85} is adjusted in the required direction to compensate this effect, and R_{100} is again adjusted until the spot sweeps across the centre of the graticule. This examination and adjustment is repeated, until the slope of the trace is negligible at all start potential settings. If this condition cannot be achieved the input pair are replaced by more closely matched valves.

The shift voltage for the amplifier is produced by the network R_{80}-R_{84}. The potentiometer R_{84} is a high grade Colvern type, fitted externally with mechanical stops to ensure that the slider does not run off the track. The control knob for the potentiometer carries an engraved dial, reading from 0-200mV in steps of 1mV for an angular rotation of 300 degrees. This control may be used merely as a beam shifting device or alternatively, for the measurement of a peak height in terms of millivolts appearing across the cell load resistor. In the latter case, the peak current can be calculated as the cell series resistor is known.

The voltage appearing across the shift potentiometer may be calibrated against a standard cell, which provides a reference potential of 200mV at the junction of the resistors R_{78} and R_{79}. For this purpose the shift control is set to

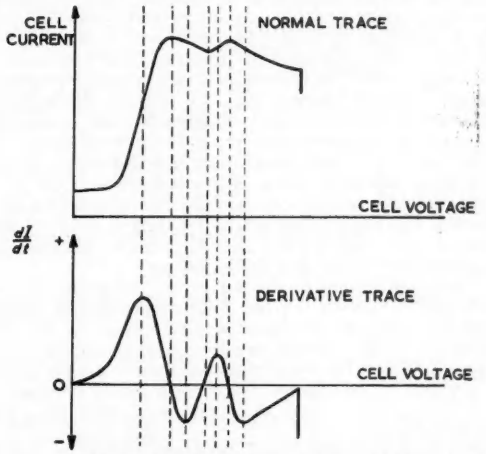


Fig. 7. Traces obtained when examining a solution containing cations due to two elements with adjacent reduction potentials

the 200mV mark and S_3 is set to the "Calibrate" position. The amplifier and cathode-ray tube then function as a null indicator and R_{82} is adjusted until no deflexion of the cathode-ray tube spot occurs when the input grids of the amplifier are shorted together by means of S_5.

Differentiating Circuit

The switch S_2 enables the cell current waveform to be fed to the Y amplifier through the coupling C_{13} R_{77}. The time-constant of this coupling is only five milliseconds and the trace then corresponds approximately to the time derivative of the current waveform. Definite maxima and minima are exhibited by the derivative waveform, even where the peaks on the normal trace have become merged because the difference between their reduction potentials is small (Fig. 7).

It is not claimed that the derivative trace has more than qualitative significance but it is useful in the preliminary examination of solutions. Sensitivity is, of course, considerably reduced and it is necessary to increase the value of cell load resistor to about twenty times that required for examination of the normal trace.

Cathode-Ray Tube Circuit (V_{24})

This is of the conventional type and embodies the usual controls for brilliance (R_{123}) and for focus (R_{120}). A brightening waveform is derived from the X amplifier

output and applied to the grid by means of the differentiating network C_{19} R_{117} thus enabling satisfactory beam brightness to be obtained during the sweep, without risk of burning the cathode-ray tube phosphor during the quiescent period.

Astigmatism in the tube can be controlled by adjustment of R_{66} and R_{111}, which vary the mean voltage levels of the output valve anodes in the X and Y amplifiers respectively.

The graticule for the cathode-ray tube measures 10cm by 10cm and is divided into millimetre squares.

Stabilized Power Packs

Three main supplies are used:

(*a*) *Main 325V, 150mA Supply*

This circuit provides output voltages of 250, 75, 0 and −75V, relative to chassis, for the D.C. amplifiers. These voltages are derived from tappings on the resistance chain R_{145} R_{146} R_{147}, which also controls the stabilized current supply to the heaters of V_9, V_{10}, V_{13}, V_{14}, V_{17}, V_{18}, V_{19}, V_{32} and V_{33}.

The circuit is based on the design due to Miller[9] suitably modified to provide the required overall output voltage and to enable advantage to be taken of the high stability reference voltage provided by the Mullard type 85A1. The output, which is controlled by R_{153}, is set to 325V on load and R_{147} is then adjusted until the voltage between the negative supply rail and chassis is 75V. It only remains to find the correct setting of R_{162} to achieve maximum stabilization of the output voltage when the mains input fluctuates by ±10 per cent about the normal level.

The primary of the transformer for this supply must be adequately screened from the secondaries. It is also preferable to connect the mains to the primary in such a way that the neutral side of the winding is adjacent to the screen.

(*b*) *Subsidiary 500V and 250V Supply*

This circuit supplies the necessary power at the 500V level for the anodes of the final stages of the deflexion amplifiers and also provides a 250V line for the sweep generator. This circuit draws a varying current, which cannot be taken from the potential divider across the main supply unit as the voltage distribution would be upset. The 500V line is also used as a reference potential for the E.H.T. stabilizer.

The output of the series stabilizer is adjusted to 500V by means of R_{139}, and R_{144} is set to give maximum stabilization for mains variations of ±10 per cent. The 250V output is derived from a cathode-follower V_{26}.

(*c*) *E.H.T. Supply*

The E.H.T. is obtained from a transformer fed half-wave rectifier. V_{25} defines the potential of the positive side of the supply, relative to chassis, and its grid is controlled by a potential divider R_{125} R_{126} R_{127}, connected between the negative E.H.T. rail and the stabilized 500V line. The valve thus functions as a series stabilizer and R_{126} is so adjusted that, with the normal mains supply voltage, the E.H.T. output is about 4 000V negative, relative to chassis.

The stabilizer valve must have a high amplification factor and, as it is required to absorb the fluctuations of the unstabilized E.H.T. voltage, must also have excellent anode insulation. These requirements are met by the MS/Pen-T, which has a top cap anode.

It is essential that the E.H.T. voltage shall not be switched on until the 500V reference is available, as the full E.H.T. voltage will otherwise appear across the stabilizer, because of the large negative potential applied to its grid. To prevent this, the mains supply to the E.H.T. transformer is switched in by a relay RL/S_6, which is energized by means of the 500V line.

Constructional Details

The general layout of the apparatus can be seen from the photograph. The sweep generator, synchronization circuit and compensation circuits are grouped on the top chassis, the C.R.T. and the deflexion amplifiers are on the middle chassis, and the power supplies are housed in the bottom of the rack.

The panel controls are as follows, reading from left to right:

Top Chassis.

X shift R_{59}. Start potential R_{29}. Capacitor current compensation R_{25}.

Middle Chassis.

Sensitivity S_1. Normal/derivative S_2. Brilliance R_{123}. Focus R_{120}. Measure/calibrate S_3. Y shift R_{84}. Calibration key S_5.

Paralysis time (R_{16}) and sync. sensitivity (R_{19}) controls are mounted behind the panel of the sweep generator chassis and holes are provided so that they can be adjusted by screwdriver without removing the chassis from the rack. The variable resistor R_{82} controlling the voltage across the Y shift potentiometer is similarly mounted behind the panel of the amplifier chassis.

The usual precautions which are desirable in the construction of D.C. amplifiers[10] as regards matching of valves, layout of components, shielding from draughts, etc., have been taken throughout the apparatus in order to reduce drift.

The matched EF37As for the input stages of the amplifiers are selected by measuring the anode currents of a number of well aged valves at grid voltages of −1·6, 1·8 and 2·0V, with anode and screen at 75V and heater current 150mA. Pairs are chosen for equality of anode current and mutual conductance.

The cell is connected to the instrument by means of a coaxial cable. The inner conductor is taken to the cell anode and the braiding is connected both to the cell cathode, via the mercury reservoir, and to the electrode stand. The apparatus is provided with an earth line, independent of the mains, which is connected directly to the cell cathode terminal.

Operating Procedure

With the prepared cell connected to the apparatus, the rate of the dropping mercury cathode is adjusted until the sweep generator is synchronized.

If the composition of the sample to be analysed is unknown, the required range of cell potential is swept in sections by progressive adjustment of the start potential control, e.g. the range 0·2V can be completely covered with adequate overlap by setting the start potential at 0, 0·4, 0·8, 1·2 and 1·6V, since the amplitude of the voltage sweep is about 0·5V.

The instrument has the great merit that the sensitivity can be varied, if desired, for each successive sweep, i.e., every seven seconds, whereas the sensitivity of the conventional instrument cannot normally be altered during the time taken to record one trace, which is about ten minutes.

A qualitative examination of the solution can thus be carried out very speedily. This examination enables the potentials at which peaks occur to be determined as already described in the section on the X amplifier, and forms the basis for subsequent quantitative analysis.

The isolation and measurement of the peak due to a particular ionic species is carried out by setting the start potential at a slightly lower value than that corresponding to the peak. All ionic species having lower reduction potentials than the required species consequently undergo reduction during the quiescent period and the currents due to these reductions are thus diffusion controlled. Because of this the first portion of the trace obtained when the sweep starts is horizontal and forms a convenient datum for measurement of the ensuing peak.

The peak height is adjusted to a suitable value, by means of the sensitivity switch, and it is then measured

either by using the cathode-ray tube graticule or by means of the calibrated Y shift control. The corresponding ionic concentrations are determined by comparing the results with those obtained from standards under the same conditions, or they may be calculated from Randles' equation.

Advantages

The advantages of the instrument may be summed up as follows:—

(a) The maximum sensitivity is about one hundred times that of the photographic type of polarograph. It does not follow, however, that such extreme sensitivities can always be employed, as this will depend on the nature of the solution to be analysed.

(b) The analysis of a solution containing a number of ions can be carried through in a few minutes. This is the case, even when their concentrations differ widely, as a new setting of the sensitivity control may be employed for each ion.

(c) The peaks due to ions reducing at voltages only 30-40 millivolts apart can be resolved.

(d) Staff can readily be trained in its use because the steps are under continuous observation and the effects of changing a control setting are immediately obvious.

(e) Where permanent records are required, these may be secured by photographing a single trace with a suitable oscilloscope camera. A succession of such records may be made on a solution containing several ions with the same advantages as regards speed that were mentioned in (b) above.

Acknowledgments

The authors wish to express their thanks to Mr. A. S. Nickelson for valuable advice on polarographic aspects of the design, and to Mr. G. F. Reynolds for suggesting improvements as a result of his extensive practical experience of the instrument.

Acknowledgment is also made to the Chief Scientist, Ministry of Supply, by whose permission this article is published.

The apparatus described is now manufactured by Messrs. Southern Instruments Co., Ltd., under licence from the National Research Development Corporation, London, W.1.

REFERENCES

1. Kolthoff, I. M., Lingane, J. J. Polarography. Interscience N.Y.
2. Randles, J. E. B. British Patent No. 631 459.
3. Randles, J. E. B., Airey, L. Application of the Cathode Ray Oscillograph to Polarography. *Analyst 72*, 301 (1947).
4. Randles, J. E. B. A Cathode Ray Polarograph. *Trans. Faraday Soc. 44*, No. 305, Part 5 (1948).
5. Weidmann, S. Thesis, University of Berne (Switzerland), 1947.
6. Snowden, F. C., Page, H. T. *Analyt. Chem. 22*, 969 (1950).
7. Davis, H. M. British Patent Application No. 15 139/51.
8. Davis, H. M. British Patent Application No. 6 250/53.
9. Miller, H. W. *Electronics* (Nov. 1941).
10. Harris, E. J., Bishop, P. O. The Design and Limitations of D.C. Amplifiers. *Electronic Engng. 21*, 332 (1949).

The Characteristics of Some Large-Current Glow-Discharge Tubes

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E.

THE characteristics of certain glow-discharge voltage-regulator tubes have been studied and described by several independent investigators including Kirkpatrick[1], Titterton[2], Cain[3], Clucas and the author[4-7]. Most of the previous work has, however, been concerned with the relatively-low-current tubes, although some 75mA types have received attention. It does not seem to be generally realized that there are some useful glow-discharge tubes available which cover a wide range of current and for which the maximum current is about 200mA. The tube CV1199 (NS2) is one of this type, its specified current range being 30/180mA and its normal running voltage 97·5V. It might be expected that, in view of the large maximum current, the stability of such a tube would be rather poor, but no information appeared to be available to check this.

The author has recently studied the short-time behaviour of 12 new CV1199 tubes and the results obtained are briefly reported below. It will be seen that the stability of this type of tube is reasonably good.

STRIKING VOLTAGE
Limits: 111-125V
Average value: 116·5V
Specified value: 140V (maximum)
Maximum variation observed for a single tube when striking thirty times at ½ minute intervals: 2·5V.

RUNNING VOLTAGE (for complete current range)
Variations from tube to tube: 88·2-105·7V
Variations for a single tube: 3·4V maximum
2·2V average

TEMPERATURE COEFFICIENT OF RUNNING VOLTAGE (at tube current of 50mA)
Maximum: −0·28mV/V/°C
Average: −0·17mV/V/°C

INITIAL DRIFTS (at tube current of 180mA)

Maximum positive drift (percentage of running voltage):	0·18
„ negative „ „ „ „ „	4·18
Average positive „ „ „ „ „	0·06
„ negative „ „ „ „ „	3·48
Time for running voltage to become steady:	21min maximum 18min mean.

One tube was still drifting rapidly at random after 20 minutes' operation.

The value of 4·18 is greater than any previously published figure[4], but might have been expected because of the large current and consequently temperature rise of the tube.

EXTINCTION VOLTAGE
Minimum 88·5V
Maximum 96·0V
Average 91·2V

REFERENCES

1. Kirkpatrick, G. M. Characteristics of Certain Voltage Regulator Tubes. *Proc. Inst. Radio Engrs. 35*, 485 (1947).
2. Titterton, E. W. Some Characteristics of Glow Discharge Voltage Regulator Tubes. *J. Sci. Instrum. 26*, 33 (1949).
3. Benson, F.A., Cain, W. E., Clucas, B. D. Variations in the Characteristics of Some Glow Discharge Voltage Regulator Tubes. *J. Sci. Instrum. 26*, 399 (1949).
4. Benson, F. A. Initial Drifts in Running Voltage of Glow Discharge Regulator Tubes. *J. Sci. Instrum. 27*, 71 (1950).
5. Benson, F. A. Variation in Extinction Voltage of Glow Discharge Voltage Regulator Tubes. *J. Sci. Instrum. 28*, 186 (1951).
6. Benson, F. A. The Characteristics of Miniature High Stability Glow Discharge Tubes. *J. Sci. Instrum. 28*, 339 (1951).
7. Benson, F. A. A Study of the Characteristics of Glow Discharge Voltage Regulator Tubes. *Electronic Engng. 24*, 396 (1952).

* *The University of Sheffield.*

A Range of 400c/s and 1 600c/s Transductors for Service Use

By A. G. Milnes*, M.Sc., and C. S. Hudson*, B.Sc., Ph.D., Whit. Sch.

Standardization of transductors for Service use is discussed and details are given of a range of auto-self-excited transductors. These designs are for supply voltages of 13, 25, 50, 115 and 200 volts R.M.S. and cover the power range up to 85 volt-amperes as single units. In three-phase connexion the power range is extended by a factor of up to three.

Current amplifications of between 20 and 180 are obtained with the recommended load resistances and each transductor has three equal control windings. The core materials are Mumetal or Permalloy C for the small input designs and H.C.R. or Permalloy F for the power designs.

MAGNETIC amplifiers are being applied increasingly in servo- and regulating-systems in the Services because of their inherent robustness, reliability and circuit convenience. The basis of a magnetic amplifier is a saturable-core reactor, known as a transductor, that corresponds in some respects to the thermionic valve of an electronic amplifier.

A transductor consists essentially of two or more magnetic cores with numerous windings and therefore its construction is not difficult provided the necessary materials and winding machines are available. This need to produce the basic device has, however, tended to confine the use of magnetic amplifiers to a comparatively few people who have acquired the necessary design knowledge and experience. There is no doubt that if transductors were as readily available in the laboratory as are thermionic valves, more engineers would consider their use and would gain some first-hand knowledge of their advantages and limitations.

General agreement is now possible on what constitutes good design practice, although a few years ago this was not so. Therefore differences between designs tend not to be fundamental and some measure of standardization has become practicable.

Details are given later of designs that it is proposed to standardize and make readily available to Service users. It would clearly not be practicable to confine the transductors used in Service applications of magnetic amplifiers to a few standard types, and this is not the intention of the proposed standardization action. But it is hoped that these available designs will be suitable for bread-board versions of amplifiers in trial applications. At a more advanced stage in any project it may be essential to tailor-make the transductor to suit the particular problem. In many instances it is expected that different control input winding arrangements will be required on otherwise standard transductors.

The great majority of magnetic amplifiers in Service applications are designed for supply frequencies of either 400c/s or 1 600c/s. At low supply frequencies, tranductor sizes and time-constants are large and this limits their application at 50c/s.

A Survey of Existing Transductor Designs

An analysis has been made of the transductor designs used in a jet-pipe temperature control amplifier; a voltage and frequency controller for an invertor; a mixing amplifier for a blind landing apparatus; a thermocouple amplifier with a pen-recorder output; and two auto-pilot amplifiers. These magnetic amplifiers contained 14 different transductor designs—neglecting minor differences between input winding ratios.

Of these transductors, six were of auto-self-excited type, seven were of series type with separate self-excitation, and one was of bias type with overall feedback. The present trend in new designs is towards auto-self-excited connexions since the advantages of these types, namely reduced copper loss and lower internal resistance, are now more fully realized than a few years ago.

Nine of the transductor designs were input or early-stage types required for sensitivity and not for an appreciable power output. The supply voltages of these transductors ranged from 10 to 22 volts and all except one had cores of Mumetal type material. Almost without exception, these input transductors were used as pairs in push-pull circuits.

The remaining five transductors were output types designed to work up to their limiting thermal ratings. The supply voltages were 90, 100, 115, 200 and 230 volts and the core materials were Mumetal, H.C.R. and Crystalloy

Of the 14 designs, eight had three or more control windings and in addition bias windings were present in the majority of the designs for trimming purposes. The ratios of control winding to main-winding turns tended to be low and values of between a half and unity were common. This represents good design practice since the time-constant is proportional to this ratio for a transductor of given voltage amplification.

For a series transductor the time-constant is related to the voltage amplification by the equation:

$$\tau = 1/4f\left(\frac{dV_{av}}{dV_c}\right)N_c/N_a \quad \ldots\ldots\ldots\ldots (1)$$

where f is the supply frequency

V_{av} is the gross average load voltage

V_c is the control voltage

N_c is the number of control turns

and N_a is the number of main-winding turns per core.

For the parallel auto-self-excited connexion the number of main-winding turns per core, N_a', is twice that for the equivalent series transductor and the corresponding time-constant equation is:

$$\tau = 1/2f\left(\frac{dV_{av}}{dV_c}\right)N_c/N_a' \quad \ldots\ldots\ldots\ldots (2)$$

The significance of these equations is that for a low time-constant, the voltage amplification of a transductor

* *Royal Aircraft Establishment, Farnborough.*

should be obtained, as far as practicable, by positive feedback action (self-excitation) and not by the use of large numbers of control turns occupying a considerable part of the total winding space.

In the designs examined, the control winding resistances were distributed in value between 8 and 860 ohms with a median value of 40 ohms. This wide variation of input resistance can hardly be provided in a limited range of standard designs.

Toroids versus Laminations

A range of special laminations, E-shaped with double-width yoke for over-lap assembly, has been developed for transductor cores of high permeability. These laminations have saturation characteristics that are only a little inferior to those of strip toroidal cores. However toroidal construction makes more effective use of the material and is usually somewhat less in weight than the equivalent transductor with lamination cores, since the toroidal construction is a compact shape well suited for canning. Care and experience are needed for toroidal winding if the results are to be satisfactory.

Toroidal core sizes for the transductors have been taken from the range shown in Table 1.

TABLE 1

A Range of Toroidal Core Sizes suitable for Transductors

CORE NO.	INTERNAL DIAMETER (inch)	EXTERNAL DIAMETER (inch)	STRIP WIDTH (inch)	MAGNETIC CROSS-SECTL. AREA (sq. cm.)
13/2	$\frac{13}{16}$	$1\frac{1}{16}$	$\frac{1}{8}$	0·10
/4			$\frac{1}{4}$	0·20
/6			$\frac{3}{8}$	0·30
15/4	$\frac{15}{16}$	$1\frac{5}{16}$	$\frac{1}{4}$	0·30
/6			$\frac{3}{8}$	0·45
/8			$\frac{1}{2}$	0·61
16/4	1	$1\frac{1}{8}$	$\frac{1}{4}$	0·40
/6			$\frac{3}{8}$	0·61
/8			$\frac{1}{2}$	0·81
20/3	$1\frac{1}{4}$	$1\frac{7}{8}$	$\frac{3}{16}$	0·38
/6			$\frac{3}{8}$	0·76
/9			$\frac{9}{16}$	1·13
24/3	$1\frac{1}{2}$	$2\frac{1}{4}$	$\frac{3}{16}$	0·45
/6			$\frac{3}{8}$	0·91
/9			$\frac{9}{16}$	1·37
28/3	$1\frac{3}{4}$	$2\frac{5}{8}$	$\frac{3}{16}$	0·53
/6			$\frac{3}{8}$	1·06
/9			$\frac{9}{16}$	1·58

If the power into the load is to be large for a given volume of transductor, analysis shows that tall transductors with cores of large strip width are preferable. A further advantage of these proportions is that the plan-area is small and this is usually convenient. On the other hand, the maximum height of transductor that can be wound is limited (say to 2in.) by the dimensions of the winding machine shuttle. The ratio of height to plan dimensions is also limited by the difficulty of press-drawing exceptionally tall cans in steel.

Auto-self-excited Transductors

Output stage transductors should be designed with ratings corresponding to the thermal limits so that the maximum possible powers are obtained from given core sizes. At the full output condition copper losses are responsible for the temperature rise in a transductor. (The iron losses are usually small and become almost zero at the full output condition, since the flux changes are then small.) In this respect the auto-self-excited transductor connexion is advantageous, since its copper losses are only one-half of those of the equivalent series transductor, because the load current flows in alternate parallel paths in each half-cycle instead of continuously in each winding.

A further advantage of the auto-self-excited connexion is that the internal resistance is lower, because the main windings are not all in series, and this tends to permit a slightly increased output voltage. The amplifications of the auto- and separately-self-excited connexions are identical in theory and usually nearly so in practice. It follows that for the power transductors of the standard range, the auto-self-excited connexion is the natural choice.

With input type transductors the thermal limits are rarely reached because the currents are small and therefore either auto- or separately-self-excited transductors may be used. In the standard range it was originally intended to have

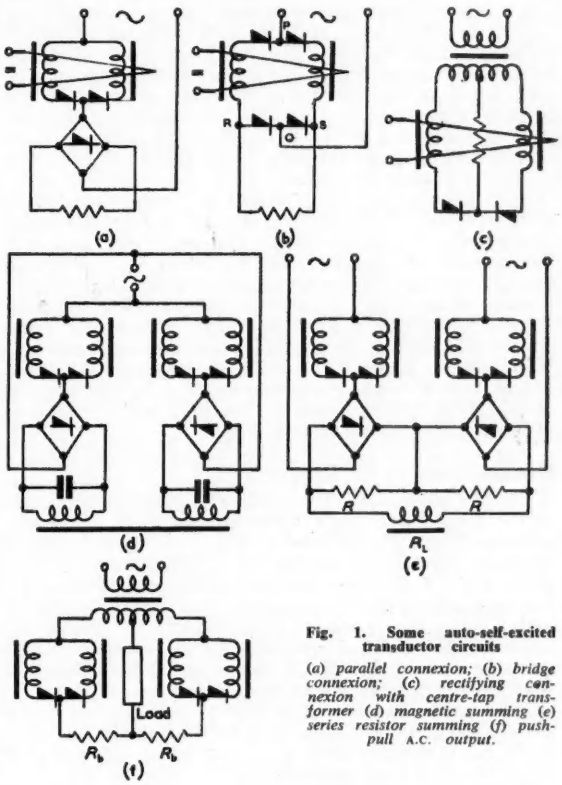


Fig. 1. Some auto-self-excited transductor circuits

(a) parallel connexion; (b) bridge connexion; (c) rectifying connexion with centre-tap transformer (d) magnetic summing (e) series resistor summing (f) push-pull A.C. *output.*

the main element windings in two parts so that either of these connexions could be used at choice. However, this proposal was dropped in favour of simple auto-self-excited types because of the practical difficulty in the provision of the necessary numbers of terminal seals on cans of small plan area. For the same reason it was decided not to provide special gain adjustment windings on the auto-self-excited designs. It is intended that any gain adjustment of these types shall be by change of load resistance; by shunt resistor across the auto-self-excitation rectifiers; or by use of a spare control winding for overall positive or negative feedback.

Some auto-self-excited transductor circuits are shown in Fig. 1 for single units and for push-pull pairs. Of the single-unit circuits (a), (b) and (c), the parallel connexion has the advantage that the reverse voltages across the auto-self-excitation rectifiers are low. For this circuit the

mean reverse voltage depends on the transductor current and its winding and rectifier forward resistances, whereas in the bridge and rectifying connexions the reverse voltages are more directly related to the supply voltage. The reverse voltages should not be greater than 10 volts peak for a double-voltage (25V R.M.S.) selenium rectifier disk if the leakage currents of the auto-self-excitation rectifiers are to be small and to have no influence on the transductor sensitivity under all operating conditions of temperature. With perfect rectifiers, and ideal core properties, the theoretical sensitivities of the three arrangements (a), (b) and (c) are identical.

Magnetic summing, as shown in Fig. 1(d), may be used for a push-pull output if the load apparatus has twin input coils. Smoothing capacitors across the rectifier bridge outputs may be desirable to prevent interaction effects. Where such capacitors are used a series damping resistance may be necessary to prevent resonance. If the load has a centre-tapped input winding, the transductors must be supplied from a transformer with separate secondary windings. For a single input winding to the load, the series resistor summing circuit shown in Fig. 1(e) may be used, although the presence of the resistors R causes loss of sensitivity and of power. The load resistance to summing resistor ratio should be between 0·5 and unity. An alternative push-pull arangement, not illustrated, is known as the "T" summing circuit.

If an alternating current output is required to depend in magnitude on the control current and to reverse in phase with change in signal direction, the push-pull arrangement of Fig. 1(f) may be used. To prevent an excessive current circulation between the two transductors it may be necessary to bias the cores to a low standing-current condition and to insert ballast resistors R_b. From an A.C. output that is magnitude and phase sensitive, it is, of course, possible to obtain a push-pull D.C. output by the use of a phase-sensitive rectifier or demodulator arrangement. This is sometimes found instead of the more usual summing arrangements.

General Notes on the Designs

The transductors of the range are divided into input and power types. The input types are designed for supply voltages of 13, 25 and 50 volts R.M.S. and have Mumetal or Permalloy C cores worked at a flux density of 5 000 gauss peak. For the power transductors the voltages are 115 and 200V and the cores are H.C.R. or Permalloy F with a design flux density of 11 000 gauss peak. For 400c/s operation the strip thickness of the toroidal cores is 0·004in., and this is acceptable for 1 600c/s operation, although a thickness of 0·002in. would be preferable.

Each transductor has three control windings with turns usually equal to one-half the number of main-winding turns per core. In addition there is a bias winding with a quarter of the turns of a control winding.

In the design work care was taken that the main-winding resistance was suitably small compared with the load resistance in order to maintain reasonable efficiency and a high power output from the given core size. The proportion of the winding space allocated to the main-winding was as much as $2/3^{rd}$ of the total: the design procedure was to assess the requirements of the control windings and then use the rest of the available space for the main-windings.

Current amplifications of between 20 and 100 were aimed at by designing the transductors to have suitable reactances in comparison with their load resistances. For an auto-self-excited transductor the theoretical equation for the current amplification is:

$$dI_a/dI_c = 1/\pi\ (X/R)\ N_c/N_a' \quad \ldots\ldots\ldots (3)$$

where X is the unsaturated reactance of one element and R is the total main circuit resistance including rectifier and load resistances.

The transductor power amplification, neglecting internal and rectifier resistances, is:

$$P = \left(\frac{dI_a}{dI_c}\right)^2 R/R_c \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Therefore from Equations (2), (3) and (4), the ratio of power amplification to time-constant is:

$$\frac{P}{\tau} = \frac{2}{\pi} f \frac{X}{R} \quad \ldots\ldots\ldots (5)$$

Thus the requirement of a high reactance to resistance ratio for large current amplification (see Equation (3)) is also a criterion for the ratio of power amplification to time-constant.

The reactance for a given transductor voltage may be increased by a reduction of the core area and a corresponding increase in the number of main winding turns. Such a change may require an increase in the proportion of the bobbin space allocated to the main windings. Reduction of the load resistance, as a means of increasing the X/R ratio, involves an increase in current and an increase in the transductor copper loss unless the winding resistance is reduced by a further allocation of space to the main windings.

One consequence of these design proportions is that with normal control winding resistances the ratio of control turns to main winding turns tends to be small, as discussed previously, although this ratio in itself is not an important criterion of transductor performance. For a given space allocated to the control winding it is possible to increase the number of control turns with corresponding change of control resistance, to match the signal source impedance, without any first order influence on the power amplification or time-constant.

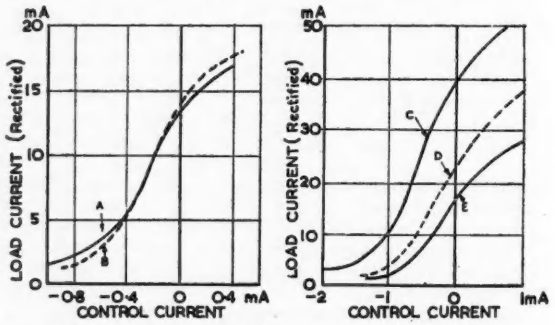


Fig. 2. Control characteristics for some input type designs

In the design calculations for the power types, the copper losses were balanced against an estimated safe rate of dissipation per square inch of surface area for a 40°C average temperature rise of the main-windings. Some attempt was made to adjust the designs so that there was no serious mis-matching between the rated transductor output currents and the normal current ratings of standard rectifier disks.

Input Type Designs

Details of the input type designs are given in Table 2 and some characteristics for certain of these designs are shown in Fig. 2.

Transductor A is a 13 volt 400c/s design which may also be used at 50 volts 1 600c/s. Thus designs E and A are identical. The load resistance for E is large because this design may be used at 1 600c/s with germanium diode rectifiers which are of large forward resistance. The characteristic for E in Fig. 2 is for a D.C. load resistance of 1 000 ohms and selenium rectifiers. Design D has half the core area of E and is suitable for 25 volts 1 600c/s operation with a load of 330 ohms.

Two designs at 25 volts 400c/s are given. Design B has twice the reactance of C and is intended for operation with a larger load resistance. The recommended load resistances are given as guides only and smaller values may be used without overheating of the transductors. The recommended values quoted are high in order that variation of rectifier forward resistance and of main-winding resistance shall not seriously disturb the balance of push-pull pairs. The current amplifications quoted in column (vi) of Table 2 are for single transductors with the recommended load resistances. If the three control windings are connected in series the gain will be correspondingly increased. The resistances in column (viii) are for single control windings and must be doubled for push-pull transductor pairs. For matching to low impedance control sources the three control windings may be connected in parallel.

The transductors are canned in push-pull pairs and the cans oil filled. Eighteen terminals are needed since there will be four main-windings, three control windings, and two bias windings for a push-pull pair.

TABLE 2
Proposed Input Type Auto-Self-Excited Transductors

DESIGN	SUPPLY		MAIN-WINDING RESISTANCE APPROX. (ohms)	RECOMMENDED LOAD RESISTOR (ohms)	MINIMUM CURRENT AMPLIFICATION PER CONTROL WINDING	CONTROL WINDING FOR SINGLE TRANSDUCTOR (3 per transductor)		CAN DIMENSIONS FOR A PAIR OF TRANSDUCTORS	
	VOLTAGE R.M.S.	FREQUENCY (c/s)				TURNS	RESISTANCE APPROX. (ohms)	PLAN (inches)	HEIGHT (inches)
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
A	13	400	40	330	20	450	40	1 23/32 square	3¼
B	25	400	60	680	20	600	50	1 31/32 „	3½
C	25	400	20	220	30	370	50	2 9/32 „	3¾
D	25	1 600	30	330	20	450	40	1 23/32 „	2⅞
E	50	1 600	40	680/1 000	30/20	450	40	1 23/32 „	3¼
F	50	400	40	680	30	600	70	2 9/32 „	3¾

TABLE 3
Proposed Power Type Auto-Self-Excited Transductors

DESIGN	SUPPLY		MAIN WINDING RESISTANCE (APPROX.)	CONTROL WINDING (3 per transductor)		PERFORMANCE ESTIMATE				CAN DIMENSIONS FOR SINGLE TRANSDUCTOR		
	VOLTAGE	FREQUENCY		TURNS	RESISTANCE APPROX.	RECOMMENDED LOAD RESISTANCE	LINEAR OUTPUT CURRENT	MEAN VOLT-AMPS OUTPUT LINEAR	MINIMUM CURRENT AMPLIFICATION PER CONTROL WINDING	PLAN	HEIGHT	TERMINALS
	R.M.S.	(c/s)	(ohms)		(ohms)	(ohms)	(amps)			(inches)	(inches)	
*G**	115V line	400	16	580	100	220	0·44	40	120	2 9/16 square	3 9/16	20
H	115	400	13	440	45	150	0·41	25	90	2 9/32 „	3½	12
I	200	400	14	600	70	220	0·48	50	110	2 9/16 „	3 9/16	12
J	200	400	8	500	100	150	0·75	85	120	3 5/16 „	4 1/16	12
K	115	1 600	10	430	50	150	0·32	15	50	1 23/32 „	2⅞	12
L	200	1 600	11	430	40	270	0·4	40	60	1 31/32 „	3 5/16	12
M	200	1 600	5	420	60	150	0·66	70	90	2 9/32 „	3½	12
*N**	200V line	400	11	700	110	250	0·70	120	180	3 5/16 „	4 1/16	20

** Three-phase transductors with six cores.*

Power Type Designs

Details of the proposed range of power transductors are given in Table 3. There are five designs for 400c/s operation—two of them being three-phase six-core transductors —and three designs for use at 1 600c/s. The three-phase designs are included because in aircraft equipment the magnetic amplifier supply is usually a three-phase 400c/s invertor and a ruling exists that the phase loadings should be balanced. Of the various possible three-phase transductor connexions, the auto-self-excited parallel arrangement shown in Fig. 3 is one of the most effective. Weight for weight its performance is as good as that of a single-phase connexion.

The two-core designs in Table 3 may be used either as single-phase transductors or as the above three-phase arrangement by the use of a two-core unit in each line. The upper limit of power handled by the proposed range in this way will be of the order of ¼ kilowatt. The estimates of performance given in Table 3 are tentative and may require adjustment when the performance of each design has been fully evaluated in practice.

Because of the difficult supply position of thin strip nickel-iron materials, some consideration was given to the possible use of grain-oriented silicon iron in place of H.C.R. or Permalloy F. A readily available grain-

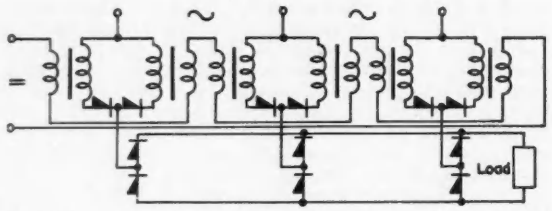


Fig. 3. Three phase auto self-excited parallel transductor with separate load rectifier bridge

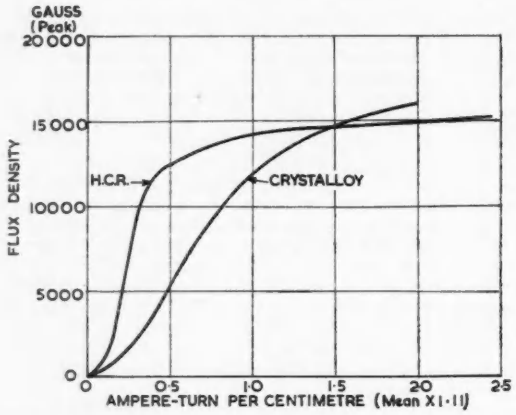


Fig. 4. Magnetization curves for H.C.R. and Crystalloy at 400c/s

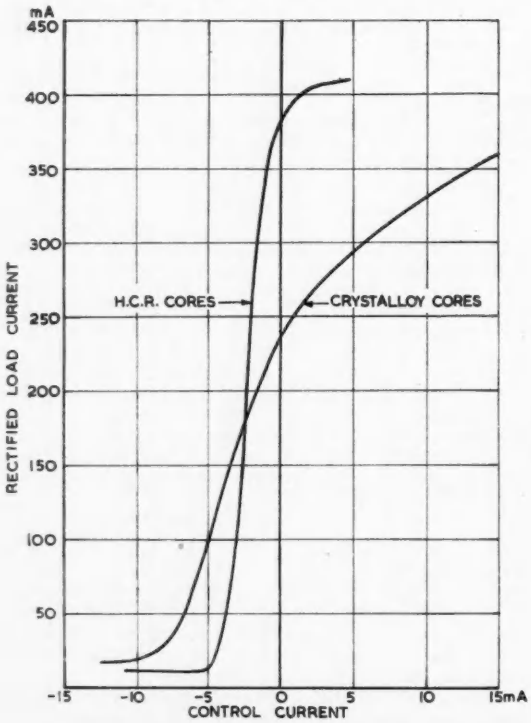


Fig. 5. Characteristics for design H with H.C.R. and Crystalloy cores
115V 400c/s; load 150 Ω

oriented silicon iron produced in this country is Crystalloy and this was used for comparative tests with H.C.R. The 400c/s magnetization curves of the two materials (H.C.R. sample 0·002in. thick, and Crystalloy 0·005in. thick) are shown in Fig. 4 and the corresponding transductor characteristics are given in Fig. 5. The useful power output for the silicon iron cores is about half of that for the H.C.R. cores and the current amplification about a third. This rules out the use of grain-oriented silicon iron except in applications where the highest standards of performance are not required.

The magnetization properties shown in Fig. 4 do not represent the best that can be obtained with these materials, which are under continuous development. For example, grain-oriented silicon iron has been produced in the U.S.A. with properties at least as good as the best curve in Fig. 4. There have, of course, been counterbalancing improvements in the nickel-iron materials. In such high grade materials there are inevitably certain batch to batch variations in properties, and the transductor designer must take care to specify the magnetization properties required.

The can sizes (based on standard C-core type cans) for the power transductors are given in Table 3. This type of canning provides excellent humidity and tropical exposure protection, but almost doubles the weight of each transductor. Consideration is to be given to other, possibly lighter, methods of protection in the near future.

Conclusion

The transductors that have been described are to be made available with fairly complete performance information and it is believed that they will be found convenient in a wide range of magnetic amplifier applications in the Services and in industry. Some further work is in hand on a range of 50c/s transductors.

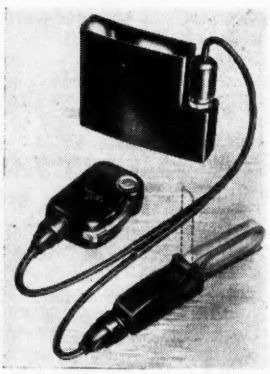
Acknowledgments

The authors have had the valued advice and assistance of Elliott Bros. (London) Ltd. and Parmeko Ltd. during the preparation of the range.

Acknowledgment is made to the Chief Scientist, Ministry of Supply, for permission to publish this article. Crown copyright reserved. Reproduced by permission of the Controller, H.M. Stationery Office.

SARAH

SARAH—Search And Rescue And Homing—is a miniature radio beacon designed and produced by Ultra Electric Ltd. It weighs 20oz and measures 7in. × 1in. × 1in. This, together with a battery unit weighing 32oz is attached to the crash survivor's life jacket. The peak output power of the beacon is 16 watts which gives a maximum range of 66 miles to a searching aircraft at 10 000 feet. The signal can thus be picked up by an aircraft within an area of 10 000 square miles. Surface ships fitted with the 24lb Sarah receiving equipment can receive the beacon's signals at a range of 6 miles. In the searching craft the signals are displayed on a cathode-ray tube. A two-way speech unit (illustrated) weighing 12 oz can also be incorporated to facilitate the final stages of a rescue. To initiate transmission the survivor has only to pull a small ring which releases a 31in flexible aerial and switches on.



An Electronic Trigger Mechanism as a Diagnostic Aid in Electro-Encephalography

By M. G. T. Hewlett*, M.B.E.

When patients are undergoing electro-encephalographic examination, the application of photic stimuli is often of great value in encouraging the brain to produce electrical discharges which may be characteristic or diagnostic of a particular disorder.

A method is described of locking such stimuli to selected frequency components present in the complex electrical signals from the brain.

This process often results in diagnostic patterns in the electro-encephalogram where other methods have failed or have produced only indefinite changes.

PRESENT-DAY electro-encephalographic technique usually involves the simultaneous recording of the potential differences arising between six or eight pairs of electrodes spaced on the surface of the subject's scalp. The complex electrical signals arising in the brain are normally displayed as six or eight "time/voltage" graphs on a continuously moving paper strip. The increasingly available data upon the departures from normal of these tracings has enabled great advances to be made in the diagnosis and treatment of a variety of neurological and psychiatric disorders.

It is known, however, that recordings taken under passive resting conditions may fail to show up specific patterns in the E.E.G. tracings which are associated with some of these disorders, and in almost all E.E.G. centres various stimulating procedures are applied to patients undergoing examination.

One of the most valuable procedures is known as photic stimulation[1], where a brilliant flashing light is placed close to the patient's eyes. The flashing rate is varied both at random and in various harmonic sequences. Frequently, abnormalities are evoked in the E.E.G. record which would not otherwise have been seen and which may aid the diagnosis of the particular disorder under investigation. An extension of this method, often called "triggering"[2,3], is where the lamp flashes are locked either to dominant peaks in the complex E.E.G. signal from certain parts of the brain, or to specific frequency components selected from the complex signal.

If arrangements are made to vary the instant of flash with respect to the start of each cycle of a selected frequency and, in some cases, if flashes are evoked at harmonics or sub-harmonics of the selected component, abnormal E.E.G. patterns may be produced which would not have been seen using free or "unlocked" photic stimulation.

A flexible and accurately controlled trigger unit was built in 1950 and was given extended clinical trials[4,5]. Its success as a diagnostic aid in routine use in a busy electro-encephalographic department was such that a new and improved version has now been produced. The ensuing paper deals with the design of this second or MKII version. Its main advantages over the original instrument lie in its greater flexibility, compactness and stability.

Description of System

A block diagram is shown in Fig. 1 and a full circuit diagram in Fig. 2.

The complex output signal from any selected E.E.G. channel is fed, via a pre-amplifier, into a resonant amplifier.

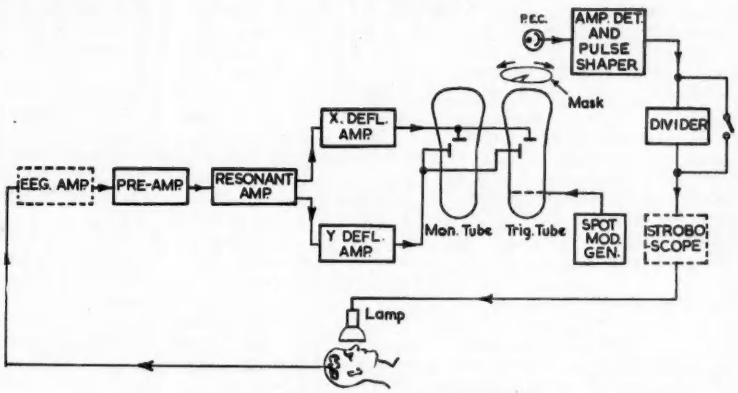


Fig. 1. Block diagram of system.
Units shown dotted are external to the trigger mechanism described.

The latter is tuneable between 2c/s and 40c/s in one range. Two sinusoidal outputs, in quadrature at the selected frequency, are available from the resonant amplifier and these are fed to the X and Y deflector plates of both a monitor and a trigger cathode-ray tube. The resulting circular trace on the trigger C.R.T. screen is viewed by a multiplier photocell mounted coaxially with the tube. An interposed circular mask is pierced by any suitable combination of slits (usually one or more equi-spaced radial slits) and a trigger pulse is generated in the photocell each time the "spot" on the C.R.T. screen passes a slit in the mask. Thus trigger pulses at the fundamental or at any harmonic of the selected frequency can be generated, and phase adjustment between the selected frequency and the pulse can be made by rotating the mask.

The trigger pulses are amplified, shaped and passed either directly to a Scophony high-power stroboscope or via a divider circuit which selects either every alternate, third or fourth pulse. This provides flashes at the 2nd, 3rd or 4th sub-harmonic of the selected frequency if required.

* *Formerly Bristol Mental Hospitals, now E.M.I. Engineering Development Ltd.*

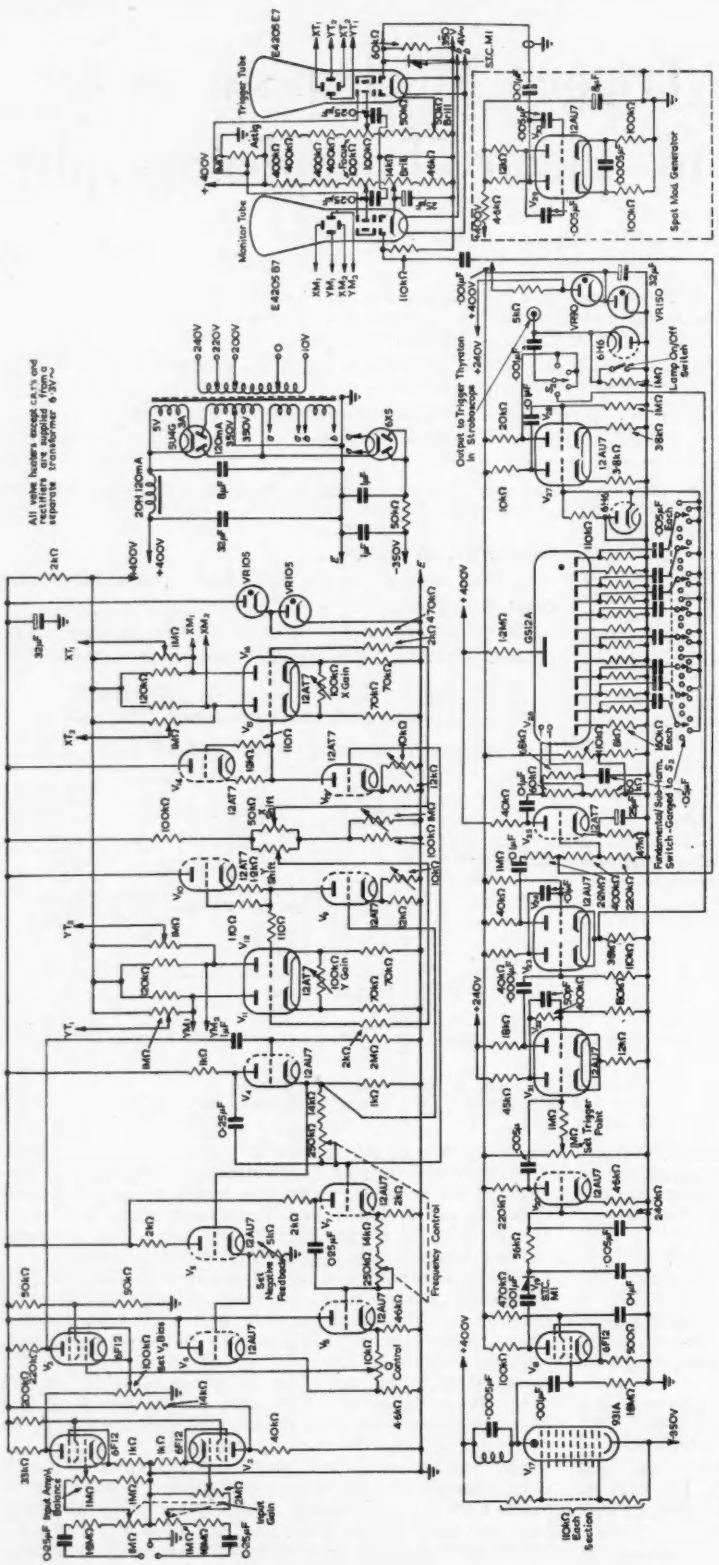


Fig. 2. Complete circuit diagram.

The Circuit

Pre-amplifier and Resonant Amplifier

The output from any selected E.E.G. channel is fed into a pre-amplifier, V_1V_2, designed for push-pull input and single-ended output. The balance of this amplifier can be adjusted to give a discrimination of at least 500:1 against in-phase signals at its input. The pre-amplifier is directly coupled into the cathode circuit of an amplifier V_3, which forms the feedback loop for a phase shift system comprising V_4, V_5, V_6, V_7, V_8[6]. The direct coupling eliminates phase shifts throughout the operating frequency band (2-40c/s) and provides bias for the loop amplifier V_8, itself directly coupled to the phase shift system, without resort to too high a value of cathode bias resistor and its attendant negative current feedback. The phase shift system, V_4, V_5, V_6, V_7, V_8, is arranged to give a phase shift of 180° at any selected frequency between 2c/s and 40c/s. The phase shift is in two stages of 90° each and is performed by the resistance-capacitance network connected between the anodes and cathodes of both V_4 and V_7. In each of the stages V_4 and V_7 a 90° phase shift occurs at a frequency where the capacitative reactance and the resistance of the networks are equal. The loop amplifier V_8 has an aperiodic phase shift of 180° and is connected between the output and input of the phase shift system. Thus a feedback system is formed and a loop gain sufficient to overcome the network losses would cause the circuit to oscillate at the frequency which satisfied the condition for a total phase shift of 360°. In this application the loop gain is reduced below the oscillation point and the circuit behaves as a resonant amplifier. Tuning in one band between 2 and 40c/s is effected by using an accurately ganged twin potentiometer for the resistive elements of the two-phase shift networks. The output from the phase shifter is fed to the aperiodic loop amplifier via a cathode-followed stage V_8, this increases the load impedance presented to the preceding stage and provides an output at a low D.C. level with respect to ground so that direct coupling can conveniently be used between V_8 and V_3. The two stages V_5 and V_6 are connected in parallel with the phase shift chain but have an aperiodic phase shift of zero degrees and thus form a negative feedback system at the resonant frequency. This use of negative feedback stabilizes the gain of the whole system throughout the frequency band and also provides a method of varying the loop gain by changing the ratio of positive to negative feedback at the potentiometer marked "Q" control.

An idea of the stability of the system may be gained by setting this potentiometer ("Q" control) so that the circuit just oscillates. Despite the absence of non-linear stabilizing elements and of any great degree of H.T. stabilization, the circuit will oscillate stably at a sub-maximal level for considerable periods at frequencies as low as 2c/s. As has been stated, the normal adjustment of the circuit is such that oscillation does not occur and the circuit behaves as a resonant amplifier. Any frequency component between 2 and 40c/s may thus be selected from the complex E.E.G. signal which is fed into the resonant amplifier via the pre-amplifier. Since the selected component undergoes a phase shift which includes two changes of 90° each, there are two outputs in quadrature available. These are taken from the cathode of V_4 and the grid of V_7 respectively, and are fed via direct couplings to two separate D.C. deflexion amplifiers V_{9-12} and V_{13-16}. The two outputs from these amplifiers are fed to the X and Y deflector plates of a 2½ inch monitor C.R.T. and a 2½ inch trigger C.R.T.

The Deflexion Amplifiers and Cathode-Ray Tubes

The deflexion amplifiers each consist of a triode cascode stage followed by a long tailed pair of triodes. Their gains can be individually controlled by variable cathode coupling resistors in their output stages and X and Y shifts for the cathode-ray tube beam are obtained by varying the D.C. level of the "free" grid of each long tailed pair.

The bias resistors in the cathode leads of V_9 and V_{13} were adjusted experimentally to ensure minimum amplifier drift under conditions of varying heater voltage[7].

A sinusoidal signal from the resonant amplifier produces a circular trace on both cathode-ray tube screens, the diameter of the trace being proportional to the peak amplitude of the signal. In normal use, since the selectivity of the resonant amplifier is finite, the traces on the cathode-ray tubes can never be perfectly circular when the input is a complex signal. However, the departure from circularity is not usually serious and where difficulty due to a high amplitude component close to the resonant frequency is experienced, the selectivity of the resonant amplifier may be increased. Increased selectivity, of course, increases the fly-wheel effect of the resonant amplifier.

The trigger cathode-ray tube has auxiliary pre-set shift controls connected across the anode loads of the deflexion amplifier output valves in order to compensate for differences in beam alignment between the two tubes. Since these controls also alter the signal level to the X and Y plates of the trigger tube independently, correct adjustment ensures good beam centering and allows for differences in the deflexion sensitivities between the two tubes. This method of correction results in a slightly smaller deflexion sensitivity on the trigger tube, but this is of no consequence. When adjusting the trace centering and circularity on the trigger tube, the auxiliary shift potentiometers are gradually reduced in turn from the maximum gain position until the correct result is secured; with monitor and trigger tubes using identical electron guns very little adjustment is necessary. The monitor tube has a green medium persistence screen and the trigger tube a short persistence blue screen.

The Trigger System, Photocell Amplifier and Pulse-Forming Circuit

A circular opaque mask clipped into a perspex carrier and a multiplier photocell are mounted in a light-tight housing in front of the trigger tube. The mask is between the tube and the cell. The mask can be rotated by an external knob and is normally pierced by one or more equi-spaced radial slits approximately 1mm wide and extending from a radius of 5mm to the edge of the mask.

When a component selected from the complex E.E.G. signal is causing rotation of the "spot" on the cathode-ray tube screen, a pulse is generated in the photocell each time the spot passes a slit in the mask. Where one radial slit is used the pulses occur at the selected frequency, with two slits spaced at 180° the pulses are at the 2nd harmonic of the selected frequency and so on. Continuous phase adjustment between these pulses and the selected component may be secured by rotation of the mask.

The mask carrier and mounting are arranged so that the mask and carrier may be ejected by raising the rotation control knob.

In order to amplify and shape the pulses from the photocell, it has been found convenient to modulate the beam intensity of the trigger tube with a comparatively high frequency square wave signal (33kc/s) generated by a cathode coupled multivibrator V_{29-30}. The photocell anode load is a resonant circuit tuned to the modulation frequency. Thus a great deal of trouble associated with the high inherent noise level of the cell and hum injected into the amplifier from the photocell supply circuits is avoided. The high frequency signal from the photocell is amplified by V_{18} and rectified by V_{19}. The carrier frequency is filtered out and further amplification of the pulse is effected by V_{20}. Negative pulses appearing at the anode of V_{20} are used to trigger a Schmidt trigger circuit which is normally biased so that V_{21} is conducting and V_{22} cut off. The Schmidt trigger circuit is adjusted so that residual noise fluctuations never reach a high enough level to trigger it and the square wave output at the anode of V_{22} is free from noise and of a pulse width determined by the rate at which the cathode-ray tube spot traverses the mask slit. This pulse is differentiated and applied to a delay multivibrator V_{23}, V_{24}. The multivibrator triggers only on positive pulses and therefore responds only to the leading edge of the pulse from the Schmidt trigger. When trigger pulses at the fundamental selected frequency are in use, the pulses are taken from the cathodes of the delay multivibrator and applied directly to the lamp firing circuit. The pulses are clipped by a diode to remove overswing due to *RC* couplings in the circuit.

When trigger pulses are required at frequencies which are sub-harmonically related to the selected frequency component, the output of the delay multivibrator is routed to an inverting amplifier V_{25} and is applied via a suitable network to the guide electrodes of a 12 cathode Dekatron counter tube. The network provides a direct and a delayed rise pulse to this tube to ensure correct glow transfer from one cathode to the next[8].

A switch selects either alternate, every third or every fourth cathode of the counter tube and connects them in parallel to the input of the isolating amplifier V_{27}, V_{28}. Thus, in addition to fundamental working, output pulses at the 2nd, 3rd or 4th sub-harmonic of the selected frequency component are available. As before, phase adjustment by mask rotation may be made. Output pulses at harmonics of the selected component require a mask with more than one slit.

Whatever combination is in use, the output pulses from V_{28} are positive and these are taken to the grid of the lamp triggering thyratron in a Scophony high power stroboscope. The "contactor" jack on this instrument was rewired and used for the pulse input from the trigger unit.

Power Supply Circuits

The cathode-ray tube supply circuits are conventional except that the high voltage supply which feeds both cathode-ray tubes and the multiplier photocell is half above and half below ground. This simplifies insulation problems and the supply which is negative to ground is obtained from a half-wave rectifier connected to one end of the H.T. winding on the mains transformer. The unbalance on this winding may be neglected since the negative supply current is less than 2·5mA. The H.T. and L.T. supplies for the other circuits are conventional. The H.T. output from the power pack is approximately 115mA at 380V. Two VR105 stabilizers are used to give a supply

at 210V for the pre-amplifier, resonant amplifier and deflexion amplifiers. Two further stabilizers are used to give supplies at 240V and 150V for auxiliary circuits.

Auxiliary Circuits

The spot modulating square wave for the trigger cathode-ray tube is obtained from a cathode coupled multivibrator V_{29}, V_{30}. The whole of this circuit is enclosed in a screening box to prevent interaction with other circuits. An output square wave of 1/1 mark/space ratio with a peak amplitude of 50V and a frequency of 33kc/s is applied to the grid of the trigger cathode-ray tube. An M1 rectifier is used at the cathode-ray tube grid to give D.C. level restoration.

In order to maintain visual monitoring of the circuit conditions, the lamp flash is indicated on the trace on the monitor cathode-ray tube as a short gap. This gap is obtained by feeding a negative pulse from the cathode circuit of V_{23-4} to the grid of the monitor cathode-ray tube.

Operation

The instrument is at present used in conjunction with an Ediswan MkII 8 channel electroencephalograph and an Ediswan MkII low frequency wave analyser. The trigger mechanism is automatically switched to whichever channel is being analysed. Usually a dominant frequency component in the alpha band (8-13c/s) is selected and the trigger gain and Q are adjusted to give a satisfactory circular trace. Triggering is started and phase adjustment is made as required to build up cerebral activity at the frequency selected. In turn, other frequencies are tried and rapid frequency changes are made up and down the band in various harmonic series. Harmonic and sub-harmonic flashes may be tried, particularly if the action of triggering produces interesting changes in the E.E.G. In many instances, patterns diagnostic of epilepsy may be evoked by this method where other procedures have failed or have produced only indefinite E.E.G. changes.

Acknowledgments

Thanks are due to Dr. E. C. Turton, Mrs. A. B. Spear, Miss J. P. Rockett and Miss V. D. Heaven for their patience in using the instrument as a routine on all patients undergoing E.E.G. examination, and to Dr. R. E. Hemphill for permission to publish this paper.

REFERENCES

1. Walter, W. G., Dovey, V. J., Shipton, H. Analysis of the Electrical Response of the Human Cortex to Photic Stimulation. *Nature. 158*, 540 (1946).
2. Shipton, H. W. An Electronic Trigger Circuit as an Aid to Physiological Research. *J. Brit. Instn. Radio Engrs. 4*, 374 (1949).
3. Walter, W. G., Shipton, H. W. The Effect of Synchronizing Light and Sound Stimuli with Various Components of the Electro-Encephalogram. *J. Physiol. 108*, (1949).
4. Hewlett, M. G. T. An Electronic Trigger Mechanism. *E.E.G. Clin. Neurophysiol. 3*, 513-*516* (1951).
5. Turton, E. C. An Electronic Trigger Used to Assist in the E.E.G. Diagnosis of Epilepsy. *E.E.G. Clin. Neurophysiol. 1*, 83 (1952).
6. Villard, O. G. Independent Control of Selectivity and Bandwidth. *Electronics*, p. 121 (April, 1951).
7. Sowerby, J. McG. Reducing Drift in D.C. Amplifiers. *Wireless World. 56*, 350 (1950).
8. Bacon, R. C., Pollard, J. R. The Dekatron. *Electronic Eng. 22*, 173 (1950).

A Very Wide Band Dummy Load

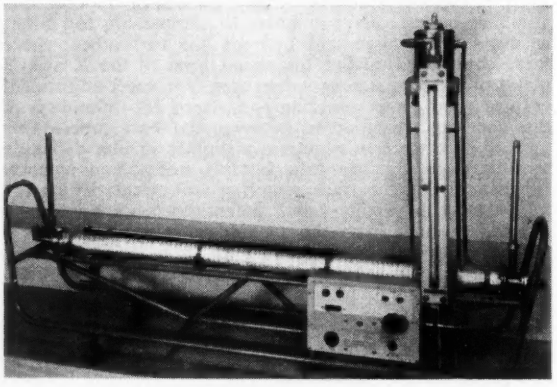
In the development of U.H.F. communications and other electronic equipment, there is an increasing need for improved methods of measuring power over a wide frequency range. This form of measurement presents a difficult problem since the method adopted depends not only on the magnitude of the power but also on the particular frequency at which it is to be measured. In such measurements it is also necessary to ensure correct matching to the source and at the same time to avoid mismatches due to the introduction of the power measuring device.

Many of the limitations set by previous methods of R.F. power measurement have been overcome in the development, at the Mullard Research Laboratories, of a very wide band dummy load. This device has been specifically designed as a high-precision measuring instrument for use in conjunction with a development project in the field of U.H.F. communications. Essentially it takes the form of a short coaxial line, filled with carbon tetrachloride, the inner conductor consisting of a very thin gold film on a glass rod. This presents a purely resistive input impedance of 75 ohms at frequencies from 100Mc/s upwards. The power absorbed by the dummy load is measured in terms of the temperature rise in the carbon tetrachloride cooling liquid between inlet and outlet of the dummy load. The rate of circulation of the cooling liquid is regulated with the aid of a flowmeter incorporated in the instrument.

The maximum power handling capacity of this new dummy load is 600 watts, and the power measurement accuracy is $\pm 1{\cdot}5$ watts or ± 2 per cent whichever is the greater. These figures refer to specific conditions set by the particular application in question. The principle on which the dummy load is based, however, is fundamental and it could be readily applied to other conditions, should the occasion arise.

In the design of this form of dummy load, the comparatively high resistance of the inner conductor results not so much from the specific resistance of the metallic film but from its extreme thinness. This results in a very small cross sectional area. The actual surface area available for cooling however, remains quite large, and the power handling capacity of a thin film resistor under these conditions is unusually high. In order to obtain uniform power dissipation throughout the whole length of the inner conductor, the resistance of the gold film is graded. This is achieved by constructing the inner conductor from a number of carefully prepared sections of varying resistance.

It is essential in a wide band dummy load to avoid any kind of discontinuity, either physically, due to a change in diameter; or electrically, due to a change in the properties of the dielectric media—the cooling liquid—filling the coaxial line. In this development it was therefore necessary to find a cooling liquid and a solid dielectric having as far as possible identical dielectric properties. Carbon tetrachloride and polyethylene were found to satisfy these conditions. Carbon tetrachloride as a coolant offers additional advantages in that its specific heat is 0·2, or $1/5^{th}$ of that of water. This means that any dummy load using carbon tetrachloride will be five times more sensitive than a load using water as the cooling medium.



The wide band dummy load

Simplified Solution of Phase-Shift Networks

By R. D. Trigg*, A.M.Brit.I.R.E.

It is intended to show a method of solving complex networks with particular application to phase-shift circuits employed in RC oscillators and selective amplifiers.

With certain provisions, the operator j is eliminated from the treatment until the final stages of the analysis is reached. The method considerably reduces the complexity normally met with in such analyses, and leads to greater accuracy.

Three examples are given relating to the single-phase pentode oscillator, Wien bridge oscillator, and the parallel-T null network.

IN the solution of *CR* ladder, Wien bridge, parallel-*T*, and other networks for phase-shift oscillators and selective amplifiers, the employment of the conventional j-notation throughout the treatment, can involve considerable labour and complexity. It is possible, however, and perhaps not generally realized, that the operator j can be omitted from almost the entire solution, and need only be employed at the final conclusion, where phase and modulus components are solved.

The method is to assume arbitrarily that all the reactive elements in the phase-shift network possess only the properties of pure resistances, and temporarily suspend their complexity from the algebraic treatment until the final stages are reached. As will be seen, this considerably simplifies the analysis, and it is to be noted, that the method can be extended to the solution of any complex network.

A comprehensive treatment of *CR* ladder networks for phase-shift oscillators has been given by Vaughan[1], and it is proposed to illustrate here the simplified method in the analysis of these and other networks.

Single-Stage Pentode Oscillators

Fig. 1 shows the equivalent circuit of a 3-mesh phase-

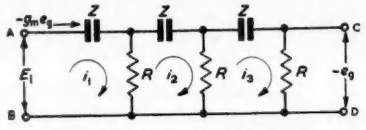


Fig. 1. 3-mesh phase-shift network

shift network which operates in conjunction with a pentode; AB being connected to its anode circuit, and CD to its input. The anode resistor of the valve is assumed large in comparison with *R*.

The criteria of oscillation are:

(1) The network shall produce a phase lead of 180° in voltage at CD with respect to AB.

(2) The valve shall have a mutual conductance g_m which produces a voltage $-e_g$ at the output of the transmission chain, when (1) is fulfilled, and when a current $-g_m e_g$ flows into it.

From the criteria we know the attenuation constant $(-E_1/e_g = \alpha)$ *is* real and negative; and from this can determine the ratio of the input and output currents given in the figure, viz:

$$i_1/i_3 = g_m R = \beta \quad \ldots\ldots\ldots\ldots (1)$$

Putting $Z = \pm jX$, $K = X/R$
where X is the reactance of each capacitor, we can write:

$$Z = jKR \quad \ldots\ldots\ldots\ldots (2)$$

and agree temporarily to regard Z as a scalar quantity, with the proviso that though it can be manipulated algebraically with respect to R, while divorced from its complex function, it can never be related numerically; i.e., it is not a simple numeral.

With this in mind, the mesh equations of Fig. 1 can be written down in the "resistive" form, as follows:

$$\begin{aligned} i_1(R+Z) - i_2 R &= E_1 \\ -i_1 R + i_2(2R+Z) - i_3 R &= 0 \\ -i_2 R + i_3(2R+Z) &= 0 \end{aligned}$$

and i_3 solved from the determinants

$$i_3 = \frac{\begin{vmatrix} R+Z & -R & E_1 \\ -R & 2R+Z & 0 \\ 0 & -R & 0 \end{vmatrix}}{\begin{vmatrix} R+Z & -R & 0 \\ -R & 2R+Z & -R \\ 0 & -R & 2R+Z \end{vmatrix}} = \frac{E_1 R^2}{R^3+6R^2Z+5RZ^2+Z^3} \quad \ldots\ldots\ldots\ldots (3)$$

whence

$$\alpha = E_1/i_3 R = 1 + 6Z/R + 5Z^2/R^2 + Z^3/R^3$$

Substituting Equation (2):

$$\alpha = 1 + 6jK - 5K^2 - jK^3 \quad \ldots\ldots\ldots (4)$$

Since α is real, the odd powers of K add to zero

$$\begin{aligned} 6jK - jK^3 &= 0 \\ \therefore K &= \sqrt{6} \end{aligned}$$

and Equation (4) reduces to:

$$\begin{aligned} |\alpha| &= 1 - 5K^2 \\ &= -29 \end{aligned}$$

This result leads to the solution of Equation (1).

Expressing i_1 in the determinantal form from the mesh equations:

$$i_1 = \frac{\begin{vmatrix} E_1 & -R & 0 \\ 0 & 2R+Z & -R \\ 0 & -R & 2R+Z \end{vmatrix}}{D} = E_1\left(\frac{3R^2+4RZ+Z^2}{D}\right) \quad \ldots\ldots\ldots\ldots (5)$$

Where D is the major determinant given in Equation (3)

Dividing (3) into (5):

$$i_1/i_3 = \frac{3R^2 + 4RZ + Z^2}{R^2}$$

this yields:

$$\begin{aligned} \beta &= 3 + 4Z/R + Z^2/R^2 \\ &= 3\ 4jK - K^2 \\ |\beta| &= \sqrt{(3-K^2)^2 + 16K^2} \\ &= g_m R \end{aligned}$$

and since:

$$K = \sqrt{6}$$

$$R = \frac{10{\cdot}24}{g_m}$$

$$X = \frac{10{\cdot}24\sqrt{6}}{g_m}$$

Wien Bridge Oscillator

In Fig. 2 is shown the frequency-selective network of the conventional Wien bridge oscillator. which employs two valves in cascade between AB and CD.

Since two valves are used E_1 and e_g must be in the same

* *Redifon Ltd.*

phase to produce oscillation, hence α is real and positive.

The impedance between A and B is:

$$Z_1 = R + Z + \frac{RZ}{R+Z} = \frac{R^2 + 3RZ + Z^2}{R+Z}$$

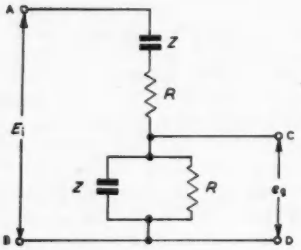


Fig. 2. Frequency selective network of Wien bridge oscillator

therefore the voltage e_g is equal to:

$$E_i \cdot \frac{(R+Z)}{R^2 + 3RZ + Z^2}\left(\frac{RZ}{R+Z}\right) = e_g$$

whence

$$\alpha = \frac{R^2 + 3RZ + Z^2}{RZ} = R/Z + 3 + Z/R \quad \ldots\ldots\ldots\ldots (6)$$

Since α is real

$$R/Z + Z/R = 0$$

or

$$1/jK = -jK$$

thus

$$K = 1$$

and

$$X = R$$

and Equation (6) reduces to:

$$|\alpha| = 3$$

Parallel-T Null Network

Fig. 3 shows the parallel-T sections used in the feedback loop of selective amplifiers.

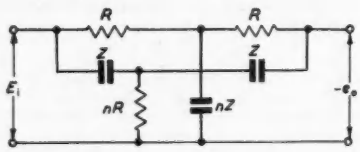


Fig. 3. Parallel-T sections used in feedback loop

Zero feedback occurs in the loop, when the voltage $-e_o$ is zero, and the network then produces a phase-lead of 180°.

The analysis is simplified when each T-section in Fig. 3 is replaced by its equivalent π-section from the following relations.

$$Z_1 = R/nZ\ (R + 2nZ)$$
$$Z_2 = R + 2nZ$$
$$Z_3 = Z/nR\ (2nR + Z)$$
$$Z_4 = 2nR + Z$$

applying these to the network in Fig. 4,

let $Z_{13} = Z_1$ in parallel with Z_3

" $Z_{24} = Z_2$ " " " Z_4

then

$$Z_{13} = \frac{RZ(R+2nZ)(2nR+Z)}{nR^2(R+2nZ) + nZ^2(2nR+Z)}$$

$$Z_{24} = \frac{(R+2nZ)(2nR+Z)}{(2n+1)(R+Z)}$$

and

$$-e_o/E_i = \frac{Z_{24}}{Z_{13} + Z_{24}} = \frac{nR^2(R+2nZ) + nZ^2(2nR+Z)}{RZ(1+2n)(R+Z) + nR^2(R+2nZ) + nZ^2(2nR+Z)}$$

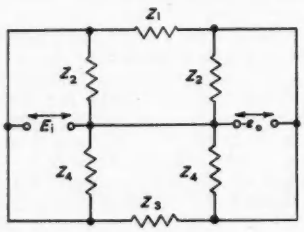


Fig. 4. Simplification of Fig. 3

Thus when $e_o = 0$

$$nR^2(R + 2nZ) = -nZ^2(Z + 2nR)$$

or

$$nR^2(R + 2jnRK) = nR^2K^2(jRK + 2nR)$$

Equating real components:

$$nR^3 = 2n^2R^3K^2$$

whence

$$K = \sqrt{1/2n}$$

Equating imaginaries:

$$2jn^2R^3K = jnR^3K^3$$

whence

$$K = \sqrt{2n}$$

$$\therefore K = 1;\ n = 1/2.$$

REFERENCE

1. VAUGHAN, W. C. Phase-Shift Oscillator. *Wireless Engr. 26*, 391 (1949).

Encapsulated Reference Resistors

By F. L. Valder*, M.I.R.E.

This article describes a method of producing reliable high-voltage resistors of a reasonable order of stability for general purposes. Their robust nature lends itself well to situations where rough handling is inevitable.

OWING to comparatively high manufacturing costs, the demand for reference resistors for use with high voltages of the order of 25-50 kilovolts has, until recently, been restricted to their use in laboratory measuring equipment. This high cost has been an embarrassment when making use of these resistors as potential dividing networks in stabilized R.F. E.H.T. equipment which merely forms part of complete apparatus, the cost of which must be pared to a minimum. It is proposed, therefore, to describe herein the construction of a reference resistor suitable for use in E.H.T. supplies and fulfilling the necessary requirements of reasonable long-term stability, low risk of open circuit conditions, high mechanical strength and economical manufacture.

The general construction can be seen in Figs. 1 and 2. Fig. 1 shows the mounting plate for carrying the individual resistor units. The plate may be of any insulating material capable of withstanding the end to end voltage stress and Perspex has been found to be excellent for the purpose.

* *Formerly Cinema Television, Ltd.*

It was also found, however, inadvisable to use synthetic resin-bonded materials, as these interfere with the setting of the polyester resins in which the unit is finally encapsulated.

Referring again to Fig. 1, the mounting strip should be as narrow as practicable, the space between the resistor mounting holes and the edge of the strip being governed only by the question of mechanical strength during the mounting operation. It will be understood that, in order to make a satisfactory crack-free polyester resin casting, the distance between the edge of the resistor mounting strip (which runs the whole length of the finished casting) and the outside surface of the casting should be not less than a certain figure depending on the stress pattern set up while the casting is forming. Thus, the narrower the mounting plate, the smaller may be the diameter of the finished casting.

A wide variety of individual resistor units have been used in experiments, the most satisfactory which the author has found being the Erie Type 8. In addition a number of tests were conducted to determine how the long term stability varied with resistance and wattage rating.

As the total value of reference resistor was to be of the order of 340MΩ, initial experiments were commenced with individual units of 10MΩ each. It was soon discovered that, with a P.D. of 25 000V across thirty-five of this value, large resistance changes occurred over a test period of some weeks, two such chains eventually becoming open-circuited. Further experiments were made increasing the

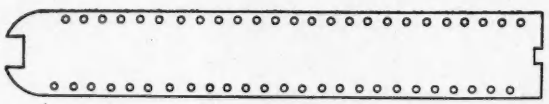


Fig. 1. The mounting strip

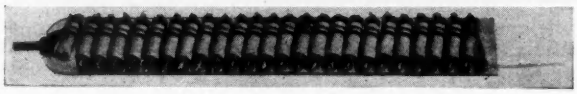


Fig. 2. A unit ready for casting

number of resistors until the stress across each resistor was as low as 500V with very little improvement in results. Various alternative unit values were tried down to 4·7MΩ, but tests proved that the compromise value of 6·8MΩ admirably met the requirements. Accordingly, a number of reference resistors were fabricated utilizing this value. Tests carried out under working conditions over a period of twelve months have shown that the long-term drift in resistance value is less than 2 per cent, the short-term stability being such that an E.H.T. unit regulated by a resistor of this type remained stable to better than 1 per cent for ambient temperature changes of 25°C.

Fig. 2 shows a unit mounted ready for casting. In this case fifty 6·8MΩ Type 8 resistors were used and it will be noted that no particular attention has been paid to stressing the resistor ends. They have been wired in series and soldered in the usual way. The high potential end terminates in a soldering tag held between the head of a bolt and a nut, while the other end, being considered "earthy", has been accorded no special treatment.

In order to construct a satisfactory mould in which to make the castings, a number of materials were tried and both Polythene and glass were found to be satisfactory. In the case of the former, the method employed was to centre-bore rod of a suitable size to the required length, diameter and shape for the finished casting, allowances being made for inevitable shrinkage. Polythene has the dual advantage that no mould release agent is required and also that it is easily machined to the desired shape. The glass moulds were formed to a shape similar to large test tubes with a small central hole in the domed end. Through this hole passes the bolt at the high potential end of the resistor unit, a liquid-tight seal being made by means of a rubber washer and a nut outside the glass mould. The use of glass as a mould produces a high gloss surface on the finished casting and a mould release agent need not be used, but has the disadvantages that mould shaping is limited and that it is much more susceptible to damage from careless handling than Polythene.

The moulding material used was Marco-Resin Type SB28C; the following formulation was found to be very satisfactory regarding setting time, freedom from cracking and crazing:

SB28C Resin	.. 200	grams
Monomer "C"	.. 4	„
Accelerator "E"	.. 4	„
Catalyst "H"	.. 4	„
Mica Powder	.. 30	„

This formulation will set in approximately 30 minutes at an ambient temperature of 20°C and will not crack if the minimum distance between the edge of the resistance mounting plate and the outside surface of the casting is not less than ¼ inch.

Due to the poor thermal conductivity of the casting resin, no attempt should be made to dissipate the normal rated wattage of the unit resistors used under the described conditions. For a chain consisting of fifty Type 8 resistors in a casting measuring 7 inches long by 1 inch

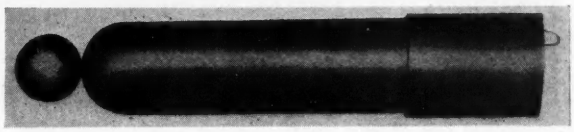


Fig. 3. The completed resistor

diameter, the maximum permissible dissipation was found to be 2 watts, and with this dissipation the required degree of stability was maintained indefinitely. The question of power rating is, however, relatively unimportant, since the applications of resistors of this type do not require a high power dissipation. Furthermore, the maximum permitted voltage across the unit resistors recommended by the manufacturers is reached before the full wattage rating is attained within the chain.

Fig. 3 shows a complete resistor with stress ball at the high potential end. The ball is also used as a terminal connector, being internally threaded to take the bolt at the top of the resistor. The physiological effect of accidental shock is minimized, to say nothing of the reduction in cost if this stress ball is made from a plastic rather than from a metal, the anti-corona properties being comparable in either case. This fact does not appear to be universally appreciated.

Finally, it should be emphasized that the reference resistors which have been described are not intended to replace expensive high-stability types designed for highly accurate measurement work. Rather do they fulfil the need for reliable, cheap and easy-to-fabricate resistors which may be included in commercial equipment with confidence if used under the conditions described.

Acknowledgment

The author thanks Messrs. Cinema Television Limited for their kind permission to publish this article.

Radio Equipment on the British 1953 Everest Expedition

By Brig. E. J. H. Moppett†, M.I.E.E., and R. W. Lewis*, B.Sc.

IN planning this year's successful expedition Col. Sir John Hunt decided that radio contact with the outside world would have slight effect upon the team's chances of success. Equipment for this purpose would necessarily be of considerable weight and its elimination permitted other more useful stores to be carried. He therefore restricted the radio equipment to that required for internal communication. This explains the much criticized delay in news getting out from the expedition. This decision enabled the radio equipment taken to be on an all-dry battery basis.

The most vital factor in timing the final assault on the summit was knowledge of the progress of the monsoon, so as to take advantage of the quiet period just before it breaks over the Himalayas. All India Radio and the BBC Overseas Service agreed to broadcast special monsoon weather forecasts for the expedition and the first radio requirement was short wave broadcast receivers to receive these bulletins.

The other radio requirement was for radio phone between climbers and between the camps on the way up the mountain, so as to be able to check and regulate the flow of stores and personnel during the build-up to get the climbers poised for the final assault. It was never the intention to use radio at the highest camps, for the assault was planned on a time-table and the weight carried had to be reduced as much as possible to allow every ounce of the vital oxygen to be carried.

The communication requirement was met by specially produced V.H.F. walkie-phones for use by the climbers, that could also be used as camp-to-camp transceivers. The sets had to impede the climbers as little as possible by weight or bulk. The battery consumption had to be low to give long use without change of batteries, and to reduce the total weight carried. Both sets and batteries had to be able to stand up without deterioration under these extreme conditions, and in tropical heat on the way to the Himalayas.

The Pye walkie-phone sets were arranged to be worn on the chest, above the oxygen apparatus, if in use, with a microphone on the top of the set, in a fixed mounting, ready for the climber to speak into at any time. A midget earphone was worn on one ear to fit easily under the head-dress. There is a press "send/receive" switch on top of the set for operation by the left thumb.

The walkie-phones operate on 72Mc/s, employing crystal control for both sending and receiving. They are set up for single frequency simplex working to allow a number of sets to work as a net. Battery consumption is so low, that with little over 2lb weight of batteries, carried under the climbers clothes, the set will operate for 90 hours. The weight of the walkie-phone itself is just under 5lb.

When in use worn by the climber, the walkie-phone employs a steel tape aerial, attached to the top of the set, sloping forward from the user. For operation from inside the tents, a tripod form of aerial was devised. This was desirable because the ground is hard rock or ice and it is not easy to drive in pegs for guy ropes. Rocks or blocks

† *Pye, Ltd.* * *Vidor, Ltd.*

of ice can be piled round the tripod legs, which can also be opened out horizontally to give greater stability under really severe conditions, with some loss of height. This same tripod was arranged to hold either the V.H.F. unipole, then constituting a form of ground plane aerial, or the vertical whip aerial for short wave broadcast reception. Twelve and thirty feet feeders allowed the tents to be in sheltered positions with the aerials sited more favourably from the radio point of view. With this equipment the climbers were able to talk from camp to camp while they and their sets were warmly tucked away in their sleeping bags.

The broadcast receivers supplied were slightly modified Pye PE70B export receivers. These are dry battery operated and have band-spread reception in the standard short wave broadcast bands, up to 18Mc/s. They were re-boxed in wood instead of bakelite to stand up to rough handling and the batteries were fitted inside the case. The same H.T. batteries as those employed for the walkie-phones were used. The boxed sets with batteries weighed 15lb.

Dry batteries give very reduced output below 0°C. It was decided to overcome this major difficulty by fitting the batteries in a waistcoat worn under the climbers clothing to maintain the batteries near body heat. Carrying the batteries like this, allowed the size of the walkie-phones to be reduced, giving a better weight distribution. The weight could be shared between two climbers by one wearing the batteries and another the set, and plugging together to use the radio.

The dry batteries for the H.T. and L.T. supplies of the V.H.F. walkie-phones and the H.F. radio receivers, had to withstand transportation through zones of relatively high temperature, and to operate in use at temperatures around zero fahrenheit, as well as being robust enough to withstand rough handling. The batteries for the walkie-phones were considered the most difficult problem. The electrical performance and make-up of the batteries finally chosen was as follows:

90V BATTERY FOR THE V.H.F. TRANSCEIVER (Vidor G1106)

The walkie-phones required 90V at 11mA for H.T. The H.T. comprised two blocks, each containing 35 Kalium cells (Vidor KV1 Cell), housed in an aluminium container and potted in a polyester resin, weighing 3¼lb in all. Tested to an end point of 65V, the life was 90 hours at 20°C, 66 hours at 0°C and 41·5 hours at 10°C.

1·5V L.T. BATTERY FOR THE V.H.F. TRANSCEIVER

The L.T. required was 300mA at 1·5V.

This battery consisted of two U.1 size dry cells 2 15/16in. high, 1¼in. diameter, connected in parallel, housed in a cardboard container waterproofed with a microcrystalline wax. This battery, except for the wax coating, is identical to the Vidor commercial type.

Unlike the Kalium cell, the frequency of use of a dry cell when loaded heavily affects its duration.

On life test to an end point of 0·1V this battery gave on continuous test 18 hours at 20°C, 11·5 hours at 0°C and 8·5 hours at −10°C, while on intermittent test it gave 40 hours at 20°C, 20 hours at 0°C and 14 hours at −10°C. The battery weighs 8oz.

BATTERIES FOR THE H.F. RECEIVER

The same type of H.T. battery as used for the walkie-phone was used for this set. The L.T. battery was the standard Vidor L5050 1·5V type. This battery gave 75 hours life even at continuous test at −10°C.

All equipment was tested at −50°C. For this temperature it was found necessary to replace PVC leads and microphone housings by rubber. The sets all worked normally at this low temperature. Considerable thought was given to the standardization of coaxial connectors and battery plugs throughout the equipment to avoid the risk of embarrassment by loss of odd parts. All plugs and connectors had to be suitable for use when wearing several pairs of gloves. The walkie-phones were fully waterproof.

The expedition took eight walkie-phones with full spares, and two broadcast receivers. The equipment was shipped out by air to reduce handling and lessen unnecessary exposure to tropical conditions on the way. Two walkie-phones and a broadcast receiver were also supplied to the Special Correspondent of *The Times* who followed the expedition out and joined Col. Sir John Hunt's party at the mountain.

On the return of the expedition to this country, Sir John spoke very highly of the performance of the radio equipment, which contributed very significantly, he said, to the well organized build-up for the final assault. The equipment and the batteries proved most reliable. The highest point at which the walkie-phone was used was 24 000ft. A set was taken to 28 000ft but sustained mechanical damage, not the fault of the equipment, and was not used there. This set remained on the South

G. Lowe, a member of the Everest team using a Pye walkie-phone with Sir Edmund Hillary looking on

Col and must be the highest piece of radio equipment on earth. Ranges of up to six miles were obtained from good sites and non-optical communication was sometimes obtained, no doubt due to a combination of the comparatively low frequency used and the reflexions from other mountains.

(Photographs reproduced by permission of *The Times*—World copyright reserved by Himalayan Committee.)

Note.—It is worth recalling that the British 1936 *Everest Expedition was equipped with radio communication apparatus for the first time. At that time it was "decided to omit the usual field telephone sets in favour of ultra-short wave transmitting and receiving apparatus, for in previous expeditions the weight of wire for a telephone service was too great for one man to carry in the rarefied atmosphere."*

Accordingly a 5 metre transmitter and receiver which, together with the batteries, weighed just over 28lb, was designed by Messrs. Eddystone, and sets were supplied to the Everest team. In his subsequent address to the Royal Geographical Society Brigadier W. R. Smijth-Windham indicated that over 550 messages were handled by the equipment in under six weeks.

A brief technical description of the equipment was given in our April 1937 *issue.—Ed. E.E.*

The Electrical Synthesis of Musical Tones

By Alan Douglas

(Part 2)

Tonal Intervals ; Total Degradation ; Tonal Characteristics of Physical Instruments ; Electronic Tone Generators

BEFORE the production of complex musical sounds is examined, the properties of the musical scale should be noted. No purpose can be served by comparing the natural or just intonation scale with the equally tempered scale, since all keyboard and most other instruments must use the latter, in order to be able to play with other instruments in any key.

The equally tempered (E.T.) scale is an adjustment of the natural scale by equalizing the ratios of each adjacent semitone to the value of $\sqrt[12]{2}$, a ratio of 1·05946. This means that the equal temperament frequency will not correspond with the true harmonic frequency for many intervals, and this makes it impossible to synthesize really complex tones from any electrical generators in which each source supplies a separate simple wave corresponding to the intervals of the E.T. scale. For instance, in a generator where the sources are geared or immutably coupled by positive mechanical means, the ratios of such coupling means would correspond to the intervals of the E.T. scale. A glance at Table 1 will show that while harmonics 2, 3, 4, 6, 8 and 12 might be combined, the useful

TABLE 1. Harmonic and Equal Temperament Frequencies.

HARMONIC	HARMONIC FREQUENCY	EQUAL TEMPERAMENT FREQUENCY	FREQUENCY DIFFERENCE	PERCENTAGE DIFFERENCE
1	440	440	0	0
2	880	880	0	0
3	1320	1318·51	− 1·49	−0·113
4	1760	1760	0	0
5	2200	2217·46	+ 17·46	+0·795
6	2640	2637·02	− 2·98	−0·113
7	3080	3135·96	+ 55·96	+1·81
8	3520	3520	0	0
9	3960	3951·06	− 8·94	−0·225
10	4400	4434·92	+ 34·92	+0·795
11	4840	4698·64	−141·36	−2·91
12	5280	5274·04	− 5·96	−0·113

5, 7, 9 and 11 would result in severe distortion. Even so, the use of 6 and 12 cause the tone to assume a somewhat hard nature, due to the beating of the small inharmonic content of these intervals. Thus total synthesis from a generator of this kind must be simple, although a certain richness may be achieved by adding octaves to the main tone. This is not true synthesis, but does give variety of effect. Only one generator of this type is now made commercially.

It is therefore clear that the best way to achieve real simulation is to use a generator which will, for any one fundamental pitch, also supply as extensive a harmonic series as may be thought desirable. The series will then be truly related to the pitch note and synthesis will be possible. One example of such a generator using rotating mechanically-coupled sources is in production. In this, the true harmonic series is engraved on the rotating elements, so each element is the equivalent of a series of independent sine wave generators correctly pitched.

All other generators fulfilling this condition accurately use valves as the source of oscillations.

It is apparent that, even if the generated harmonic series is exactly accurate, the discrepancy in the frequency ratios due to E.T. tuning must give rise to many beating or combination effects at various intervals of the compass, this again depending on the strength of adjacent harmonics; if these are few and widely separated the effect will be small; if many, close together, the effect will be marked, particularly if loud. The poor resolving powers of a single diaphragm loudspeaker will add further difference tones. Thus the problem of synthesizing complex sounds becomes involved, especially at high loudness levels.

The foregoing suggests that some distortion will be inevitable; but it is necessary first to consider tonal degradation. This is not the same as distortion, but implies a modification of the harmonic content of a simulated sound as compared with the original sound.

Perhaps no word in communications is so overworked as "fidelity". The question of fidelity is so conjectural that it is not possible to define the limits either way. Electrical and acoustic coloration play a large part in the tonal spectrum heard by the observer and the question of the final result is impossible of analysis; nor would this be of value, since listening conditions vary so enormously. The procedure for designing electrical circuits of low distortion and wide frequency response is well established, but that does not mean that the sound reaching the ear is undistorted or properly balanced. The deficiencies of loudspeakers, standing waves set up in rooms, resonances and damping due to sections of the room operating in a different way at different loudness levels, all tend to alter the effect of the waveform entering the amplifier output circuits. Many of these factors disappear in large buildings, but some may become worse. Generally the observer has little or no control over these aspects of reproduced sound. What he can control, however, is the waveform before amplification.

What we have to consider is, can acceptable synthesis of the kinds of tone desired be carried out by reasonable and reproducible means, and, if not, what can be cut out of any tone colour without any appreciable difference being detected?

It is common knowledge that the reproduction of musical instruments through the average radio receiver is mediocre. The tone control fetish introduces further mutilation; yet does the average listener find any difficulty in identifying the various kinds of instruments being played? The better informed musically may experience some irritation at times, but this is reasonably balanced by the fact that their sense of hearing does its best to fill in such tones as are missing. The ear always attempts to find a similarity between a sound as heard and what it knows that sound should be like.

It is further true that in some classes of musical instrument the tonal specification is not fixed or exact; an oboe always sounds like an oboe but one organ does not sound like another except in a general way. Even the violin is capable of an extraordinarily wide range of tonal texture, yet, except for the lower notes, it cannot be mistaken for anything else. So clearly there must be some-

thing which fixes the main tonal characteristics of most musical instruments, and variations can take place around this kind of "core".

All single tone producers generate a fixed band of characteristic frequencies which is known as a formant. This band exists independently of the main tone, though with it. The formant group owes it origin to the configuration and substance of the resonating part of the instrument. Fig. 11 shows a group of formant frequencies measured in 1949 for several instruments; not all of these are true harmonics. A certain minimum energy is required to excite the resonator fully, and if this is not available the tone may change; further, the formant band will not usually operate over a range of more than about three octaves. It may disappear if this range is exceeded, or it may re-appear an octave higher. In multiple tone producers like the pipe organ, each pipe has its own formant group. In the piano, formants do not really occur, owing to the flatness of response of the resonator, i.e., the soundboard.

If, then, means could be made available to produce

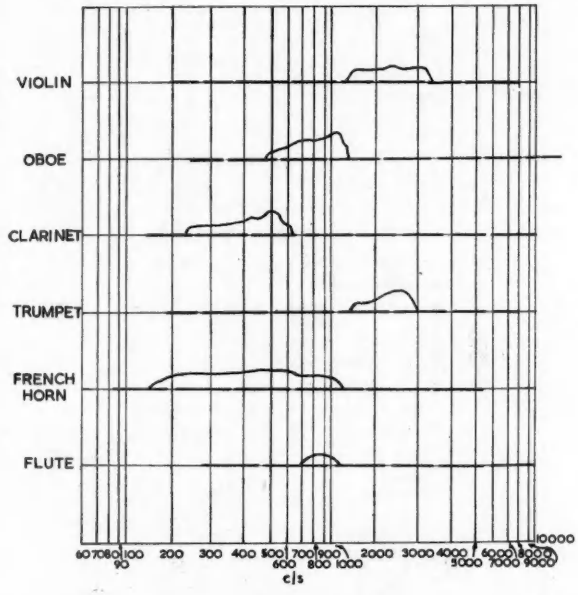


Fig. 11. Formant frequencies

synthetic formant groups, and then add or superimpose other pitches, a high degree of realism should be attainable. This is borne out in practice.

The permissible amount of tonal degradation is directly proportional to the exactitude of the tuning of the constituent harmonics, and the purity of the independent components. Analysis of a string tone (which may be held to embrace the range covered by a violin and a violincello) shows so many variations according to the construction of the instruments that, while in old violins as many as 20 harmonics have been measured, a remarkably good string tone can be generated from four or five. One of the main characteristics of all stringed instruments of the viole class is a weak fundamental. If, then, the 2nd, 3rd, 4th and 6th are present, and suitably adjusted, very passable synthesis is possible. The extreme complexity of a very "rich" string tone is a drawback and no advantage comes from attempting to imitate it; it does not have the definition and clarity of simpler string tone. The above synthesis is characteristic of the *string family*, i.e. it applies over a wide pitch range, so it may be used for the violin, viola and violincello.

Similarly, a compound of fundamental, 2nd, 5th, 6th, 9th, 10th and 12th produces a thin reedy tone which may be called the oboe or cor anglais type. By keeping the fundamental small and using 3rd, 4th, 5th, 6th, 7th, 8th, 11th and 12th, more sonorous reeds of the trumpet type are synthesized. A clarinet waveform has already been shown in Part 1. It should be noted that measured tone spectra of the foregoing instruments contain at least twice as many harmonics as those given; but the synthesized tones are remarkably good, and this is an instance of legitimate tonal degradation; for fully to compound these tones would be most uneconomical.

The ear is less ready to detect changes in the composition of complex tones than in simpler tones. Fig. 12 shows the waveform of the same note on a flute, played softly, of medium strength, and overblown. The analysis of the tones is appended. The overblown condition produces a "harmonic flute", an agreeable sound if maintained over a range of notes. Thus we might deduce that a flute-like tone need only contain few harmonics and is easily

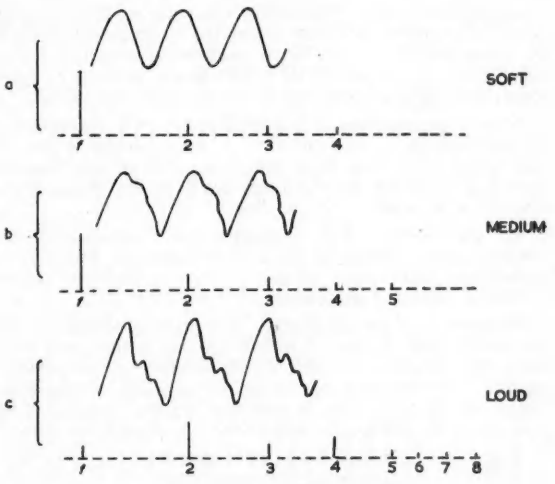


Fig. 12. Analysis of flute tones

synthesized. Of course, the pure wave from a tuning fork is flute-like, but such simple sounds rapidly become tiring and insipid, and are immediately masked and lost if other complex tones are added to them. Simple tones do not exist in any musical instrument. The amount of power required to develop a loud note from a sine wave source at 32c/s (= CCC 16ft pitch) would be phenomenal, and undoubtedly wreck any loudspeaker in a short time; but with quite a small content of 2nd and 3rd, 4th or 5th, good 16ft tones can be produced with small powers.

Some tones have special properties which allow of synthesis in the steady state but will not appear real due to other manipulative effects during playing. Such a sound is that of a saxophone. The technique of lip control and the constant changing of harmonic content due to different wind pressures, coupled with a variable vibrato, cause a synthesized saxophone to sound dull and lifeless.

Piano and other percussive tones are not successfully imitated; all electronic tones having this decay envelope are "new" tones. This is primarily because the harmonics in a normal decay wave train do not die away at the same rate, and because they inter-modulate and beat during the

decay part of the cycle. Therefore they are in constantly changing relationship and so cannot be imitated.

Having amassed some details of tonal characteristics, the next step is to see what kind of tones can profitably be synthesized by electrical means. It is almost certain that these tones are such as can be played by means of a keyboard. Most people can play a tune on keys, often because the intervals (or notes) can always be seen, partly because numbers of notes can be played at the same time, and also because the piano is the most common domestic musical instrument. Further, even if the skill exists, what possible advantages would accrue from an electrical violin, flute, or other single tone source? Only that, by means of playing keys, a number of notes could be made to sound together. The simplicity, portability and expressive playing technique of the original instrument would vanish with no commensurate gain. Moreover there would be no relative standards of loudness even if the tonal value was accurate, which would lead to forcing of the tone and prevent a balance with other instruments. This is clearly borne out by listening to electronic instruments simulating the violin; for by no manipulation of the gain control or playing keys can the delicacy of bowing be simulated. Yet for any steady state, the synthesis may be nearly perfect. This is because every movement of the violin bow generates a fresh set of harmonics and their constantly changing resonances. Therefore the tone under dynamic conditions cannot be synthesized by electric circuits and the same is true of any other orchestral instrument. The tonal spectrum of every such instrument undergoes continual change with every alteration in pitch and power.

Thus such synthesis as is effective can only reproduce a steady tone state, equivalent to a set of organ pipes of that tone; or a tone state similar to that of instruments having a restricted power range such as the flute, oboe, clarinet, cor anglais and the like.

We can decide, then, that with the exception of the electric guitar (which is not a tone generator but a tone convertor), only tones playable from a keyboard form a fruitful field for simulation.

Here we can divide sharply into three alternatives (1) instruments having a keyboard but on which only one note at a time can be played; (2) single keyboard instruments for producing percussive sounds, on which combinations of notes can be played; (3) instruments having one or more keyboards which are organesque in tone.

The single keyboard single note instrument forms a solo tone source requiring an accompaniment. It is available commercially for attachment to a piano, this being the most probable source of accompaniment. Means are provided to prevent two adjacent notes from sounding together if accidentally struck. A variety of different tones can be extracted from such devices, singly or in combination. Some simulate known tones, others are "new".

The multi-note single keyboard percussive instrument has a more limited appeal; the piano is so highly developed that unless tones of the harpsichord or spinet type are preferred, the appeal is mostly of a novelty nature. Nevertheless, some very beautiful tones can be produced by such instruments. For reasons to be explained later, no instrument of this kind is now in production.

The multi-note single or multiple keyboard instrument for sustained tones would appear to offer the greatest scope. At the outset one must recognize that all kinds of musical sounds cannot be produced in the one instrument, thus it must fall into one of the three classes above. Setting aside for the moment the domestic appeal of this latter type of instrument it is the multi-keyboard instruments of an organ-like nature which have seen the most intensive development commercially. From the constructor's point of view, such instruments are easier to co-ordinate with limited test equipment than percussive keyboard sources. Many instruments of this class are in current production.

All electronic keyboard instruments have a high degree of similarity of attack or tonal initiation for each note. The only variations possible are those of rapid change in volume by manipulation of some expression device; the introduction of a vibrato; and, in some cases, the introduction of a percussive effect. All of these factors can be introduced into any type of tone generator, so first of all typical generators will be described and, subsequently, tone forming methods. Owing to the complexity of construction, mechanical generators will not be considered except for the vibrating reed type.

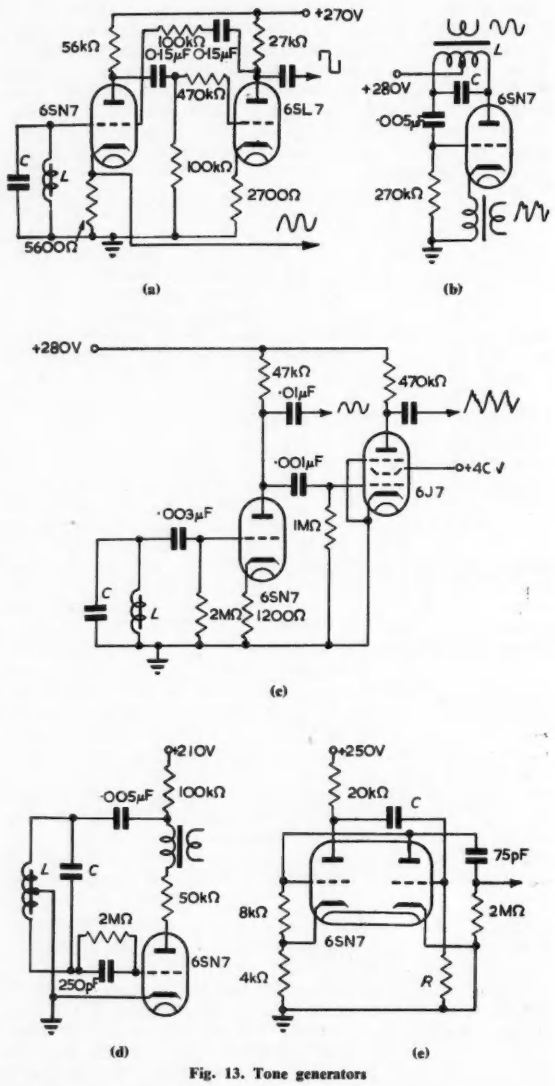


Fig. 13. Tone generators

Fifteen makes of keyboard instruments using valve oscillators are manufactured. Each of these generates a complex waveform, or more than one waveform, for every single note. Some employ one series of generators from which the different pitch ranges are extracted, others have quite separate generators for each pitch range.

Fig. 13(a) shows a very useful generator from which a

sine and square wave can be simultaneously obtained. Fig. 13(b) is a diagram of another generator giving a sine wave and also a pulse of high harmonic content. Fig. 13(c) is another way of obtaining a sine wave and one with many harmonics, the pentode being over-driven to produce this condition. Fig. 13(d) is a generator in which the output is harmonically rich. All the foregoing are *LC* oscillators and have the characteristic stability of such circuits. Fig. 13(e) is a multivibrator oscillator producing a wave of high harmonic content.

Fig. 14(a) shows a frequency dividing circuit, the output of which is rich in harmonics. Fig. 14(b) is another way of doing this, and Fig. 14(c) yet another alternative. The advantage of frequency division is that only the upper 12 tone sources need to be tuned, all other notes in octave relationship being obtained by dividers in cascade, so that if the prime source is in tune, the remaining

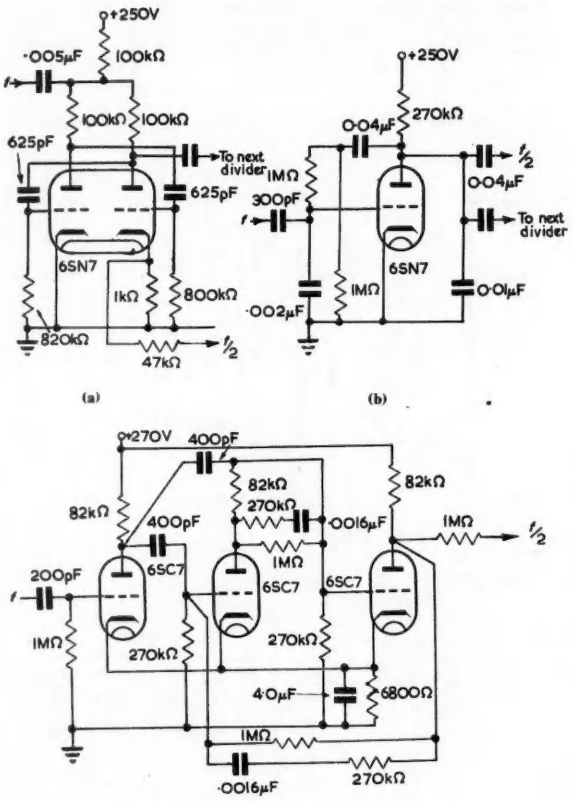


Fig. 14. Frequency dividers

divisions must be so. The disadvantage is that the waveform from many forms of divider is not entirely suitable for tone forming. All the circuits shown here are, however, in actual use in commercial instruments. They vary in complexity, some using simple triode valves, some multi-grid values, and some having more than one valve; their differing configurations being largely due to questions of policy and patents.

Circuits for generating and injecting a vibrato or tremulant usually operate on the oscillator circuits directly, before any tone forming takes place. Fig. 15(a) shows one way of generating the necessary low frequency of 6 to 7c/s, and Fig. 15(b) is another circuit. In this latter arrangement, the second valve acts as a switch to connect and disconnect small capacitors across the main tuning circuits. In the event of the grid bias having to be modulated, the grid leak may be returned to the top of the cathode resistor R_{k_2}; this vibrato voltage is cancelled by earthing the grid leak as shown. It is most important that the vibrato waveform be symmetrical on either side of the axis, or unpleasant cross-modulation results. The above circuits fulfil the required conditions.

Percussive circuits are rather difficult. One of the reasons for this is that one is not used to hearing a percussive start to the tone of, say, a clarinet, so there is no way of judging whether the effect is correct. Fig. 16(a) is one way of introducing a rapid initiation and slower decay for the sound, and Fig. 16(b) shows a more refined method.

So far it has been shown how to produce useful waveforms for musical purposes, the next step is the forming of acceptable tonecolours. The development of filters or resonant circuits for this purpose can be divided into two

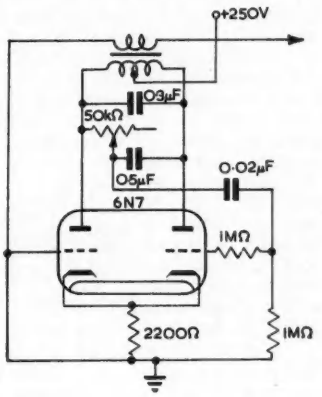
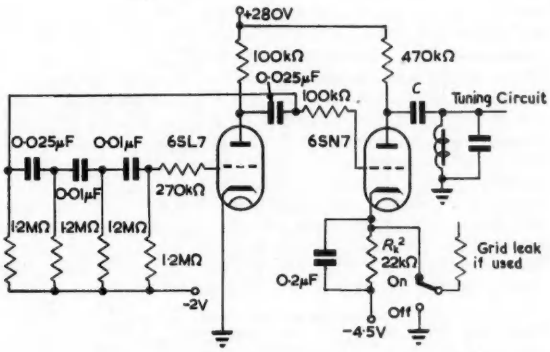


Fig. 15(a) right (b) below Vibrato oscillators



groups, those for melodic or single note instruments, and those for polyphonic or multi-note instruments. Since there is no question of combining notes on melodic instruments, we find the simplest application here in the form of shunt circuits between the signal outlet from the generator and earth.

The most elementary form of control is a capacitor placed across the line. This would be of such a value as to bypass the upper frequencies. Its response can be modified by a resistor in shunt or series with it. Such a control gives a very non-linear response and is only of use over a limited range. A much more effective control is a series-parallel network of the form shown in Fig. 17(a). By modification of the constants most tones of a flute-like nature can be produced, and four or five octaves can be covered.

It is difficult to invert this low-pass filter to a high-pass form when applied in shunt, such a filter being useful to form string tones; a better simulation being obtained

from a tuned *LC* filter resonating at the main harmonic frequency of the string formant band. If the level is kept low, the tone is good, but if it is raised too much the tone will become reedy. Such a filter is shown in Fig. 17(b). Reed tones are best simulated by other arrangements of resonant inductances, as in Fig. 17(c). It is merely a matter of placing the major resonance in the correct frequency band. Such filters will not in general cover more than three octaves, but an advantage of the shunt grouping is that several units with overlapping characteristics can be placed in series to extend the range, as in Fig. 17(d). Most of these filters produce a difference in the loudness level when others are added or subtracted. Compensating resistors can be added to equalize this. Such a circuit is shown in Fig. 17(d).

In applying filters for adding together on a large scale,

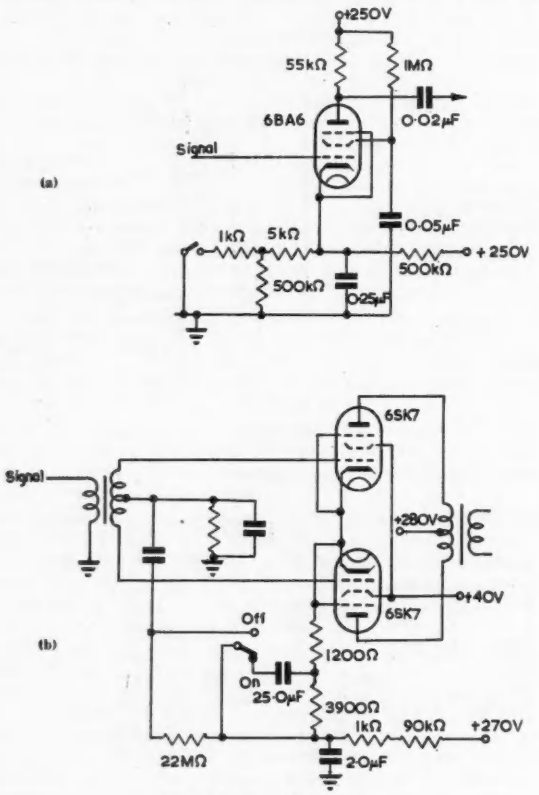


Fig. 16. Percussion circuits

these simple circuits will not suffice, multiple filters being required for electronic organs. There are two approaches to this subject. In one case, all tone-forming circuits are brought to a common impedance value suitable for combination. In the other, each tone-forming circuit feeds the grid of a separate mixing valve, the outputs of these valves being eventually combined. Additionally, more than one filter fed from more than one tone source may work into a common output. For instance, in forming a tone of the open diapason class it may be desirable to add a separate upper harmonic group to the fundamental group. This is achieved as in Fig. 18(a) by feeding the filters from tone sources separated by an octave. This means a sufficient number of contacts on the keys, two sets in this instance. It will be seen that the combination works into a resistive load and seven or eight such filters may be applied in parallel to such an input with little change in relative level.

A further extension of this method is to supply one filter from one wave shape, and another with a different wave. In the filter shown in Fig. 18(b), the very difficult

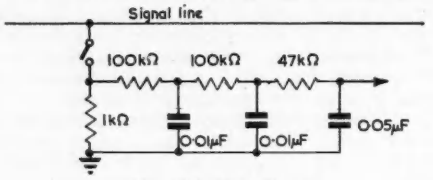


Fig. 17(a). Flute filter

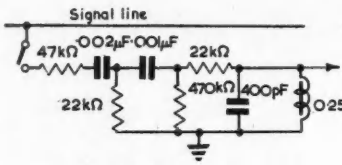


Fig. 17(b). String filter

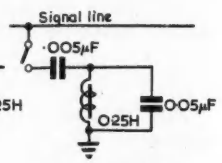


Fig. 17(c). Reed filter

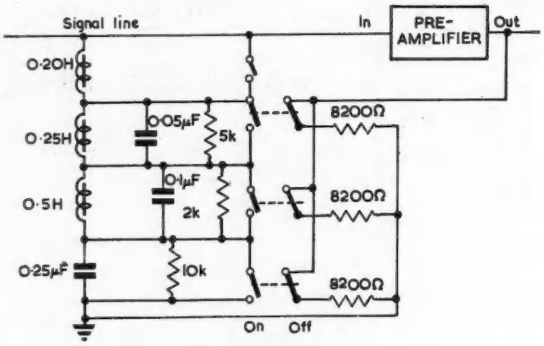


Fig. 17(d). Series filters

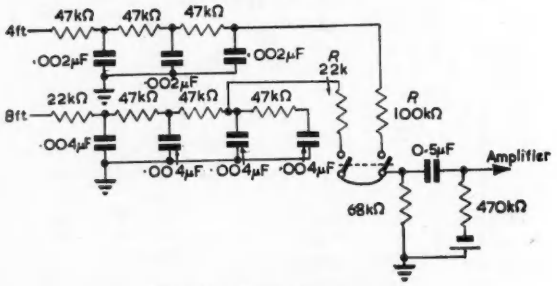


Fig. 18(a). Organ diapason filters

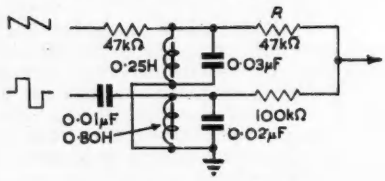


Fig. 18(b). Vox Humana filter

tone of a Vox Humana organ stop is successfully simulated.

In the above types of filter, the level for each tone-colour is set by a regulating resistor *R*. This also largely prevents one filter from reacting on another. It may be,

however, that if the filter is complex or requires many elements to produce the correct tonecolour, the attenuation becomes so high that the tone cannot attain the correct value; for, of course, there are quite definite optimum values for the range of loudness levels of different musical sounds. In this case the use of a separate tone-forming valve is desirable.

It can be seen that filter examples given do not always terminate in the correct load; in this case the attenuation is made as high as practicable, for in this case the input impedance becomes almost equal to the characteristic impedance regardless of the termination; and the loss due to mis-match rarely exceeds 2 or 3db. All the filters shown are in actual use in commercial instruments, but it will be appreciated that their effectiveness depends entirely on the shape and frequency range of the waveform supplied to them.

Fig. 19(a) shows a method by which tones are formed from the injection of two signals into a valve. The fundamental is practically free from harmonics, the pulse signal has many. Fig. 19(b) illustrates a way of doing this with

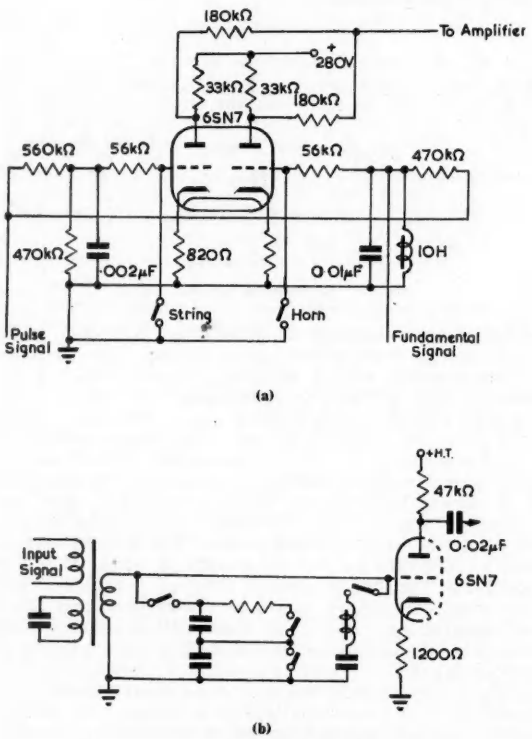


Fig. 19. Tone forming circuits

a single input waveform which contains all the desired harmonics. The regulation of the signal level for each tone is easily achieved in either of these circuits.

It will be observed that nearly all of these tone filters are of the bandpass type. This is because greater realism is obtained if circuits accentuating the formant frequency groups are inserted. At one time it was considered that true additive synthesis would give the most accurate results, and if the tone sources are quite pure and perfectly in tune this can still be the case; such exactitude of tuning can only be accomplished by mechanically coupled generators. A recent instrument employs this method using electrostatic generators.

In general, however, it has been found easier to provide complex waves from valve oscillators and modify them by means of complex filters. In a well-designed system this improves the choral effect when many tones are combined by comparison with the additive sine wave system, since there must inevitably be masking of frequencies already in use by addition of further combinations from the same sources. The unavoidable small fluctuations in tune do not appear to affect the result from the complex sources, since the whole harmonic series follows such deviations.

Since the formant groups for most instruments are well defined, the configuration of the tone-forming elements falls into three groups: (1) Resonant inductive filters emphasizing a band of both even and odd harmonic frequencies, for which purpose a triangular wave of sawtooth form is required. To these filters may be added suitably controlled fundamental and octave pitches. (2) Resonant inductive filters emphasizing odd harmonics only, for which purpose a square wave is required. (3) High- and low-pass *RC* filters into which several single frequency sources may feed. From group 1, tones of the viola, oboe, horn, trumpet and clarion type may be extracted. From group 2, clarinet, Vox Humana, stopped diapason, hohl flute, etc., are obtained. In the case of the two latter tones, the resonant peaks are flattened by shunt resistors and a strong second harmonic may have to be introduced. Group 3 provides the bourdon, diapason, flute and tibia class, for which purpose fundamental and second harmonic predominate; but the second harmonic source may be modified by a smaller degree of filtering so as to contain traces of higher harmonics. Good string tones of low intensity can also be simulated by high-pass filters in this group, the fundamental being suppressed and all other harmonics combined at almost the same amplitude.

In one pattern of mechanically coupled rotary generator the groups of harmonics necessary to provide the formant bands are engraved as an integrated series, e.g. 3rd and 5th, all odd, all even, etc.; these can then be "mixed" in various ways to produce the tonecolours.

A useful way to accentuate upper harmonics is to rectify part of the signal and so obtain pulses; by correct circuit constants very high frequencies can be produced. Rectification is also used in one commercial instrument to provide odd harmonics from a sawtooth wave source.

Undoubtedly it would result in greater fidelity over a wider pitch range if means could be found to generate, directly in the oscillators, the waveforms corresponding to the actual tonecolours required. Such a circuit does exist, and while the author is unable to disclose details of it at the moment, it will be brought to notice in due course.

The vibrating reed generator deserves brief mention. This is electrostatic, the moving tongues of the reeds acting as small variable capacitors. The overtones from a free reed are inharmonic and unpleasant, but by suitable disposition of the pick-up elements, most of these can be suppressed. The harmonic content remaining is mostly fundamental and second, but by the exercise of considerable skill coupled with special selection and adjustment of the reeds, other usable harmonics can be made available. Such generators probably owe their richness of tone to the multiplicity of small beats resulting from the slightly imperfect tuning of the many tone sources. Therefore no tone-forming in the sense previously discussed takes place, but some smoothing of the waveform is made use of to form flute-like tones. In such organs as use vibrating reeds we find only flute, diapason and string tone, but of many different pitches from 16ft. to 2ft.

A number of other matters germane to the production of synthetic musical tones will be discussed in the next section.

(To be continued)

A Study of a Second Order Sampling Servo

By S. R. Cooper*, B.Sc.

This article considers from a simple mathematical angle a second order servo working on discontinuous data, the information being sampled at regular intervals of time. The characteristic equation of the servo is obtained and two convenient parameters for studying it are obtained. Using these parameters the necessary conditions for stability are found. The transient response is considered in some detail and it is shown how the nature of it depends upon these parameters. For clarity, a similar continuous servo is treated side by side. Responses to step, velocity and accelerating inputs are considered. The response of a servo to a sinusoidal input is also considered.

THE use of servo-mechanisms in processes of automatic control is well known and the basic principles governing their behaviour are generally familiar. In the more usual servo the input information is continuously available. There are, however, a large number of cases in which the input information is not continuously available. The servo input may then be regarded as samples of some continuous function taken at regular intervals of time. In such cases the servo has to do two things, firstly it must follow exactly the input function at the actual sampling instants, and secondly it should provide smooth interpolation between these sampling instants.

The theory governing the continuous case is well known, the application of the continuous case to the sampling case can only be approximate. If the sampling frequency is high compared with any variation in the quantity to be controlled the continuous theory may be used with fair accuracy. Generally, this is not so. The mathematical theory of such systems has recently been developed[1].

This article describes an electronic system which has been built to demonstrate some of the most important aspects of the behaviour of such control systems.

Theoretical Approach

The word "servo" comes from the Latin word for slave, and this gives the clue to its behaviour. Thus, a servo-mechanism is a system which, fed with an input, will endeavour to copy this input faithfully, usually with power amplification between the input and the output.

In particular, this article deals with what are called "closed-loop" servos. This is a servo where some fraction of the output, very often unity, is fed back and compared with the input. The difference between the two which is called the error, or the correction, is then used to correct the output of the servo. The error may be either positive or negative. Such a mechanism is said to be an error-actuated device. Where precision is required the servo must have a closed loop. Although servos may take a variety of forms, e.g., mechanical, electronic, or electro-mechanical, the theory is quite general.

In practice almost all control systems are servo systems and in a large proportion of these cases the feedback loop is completed by the eye, brain and hand of a human observer. The nature of a servo-mechanism depends upon the function it is required to perform, thus servo-mechanisms vary greatly in complexity. The one this article is concerned with is given in block diagram form in Fig. 1.

In order to derive an equation determining the behaviour of the servo it is necessary to define some important quantities.

The input is the quantity, which has to be followed, controlled, etc., it is defined as $u(t)$.

The output is the path or function which the servo *actually* follows, this is defined as $v(t)$.

The rate is the derivative of the output, i.e., the input to the final integrator in Fig. 1, it is defined as $w(t)$.

The correction is the difference between the input and the output, it is defined as $c(t)$.

$$c(t) = u(t) - v(t) \quad \ldots\ldots\ldots\ldots \quad (1)$$

u, v, w, and c are all functions of time. The particular servo being considered is a simple second order servo (Fig. 1). It will be seen that the input and output are

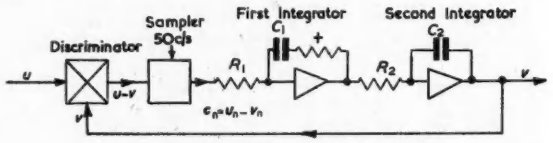


Fig. 1. Second-order sampling servo

compared in a discriminator producing a correction which may be either positive or negative in sign. The correction is then sampled with a sampling frequency of $1/T$ per second. The correction is measured at the sampling intervals and then held constant in a "box car" circuit until the next sampling instant, T-sec later, when it is erased and the new correction measured. It will be seen that by producing a continuous error and then sampling it at regular intervals, the practical case has been conveniently simulated, where it is actually the input which is only known at the sampling time. The sampled correction is integrated by two integrators in series. It will be noted that the first integrator contains a resistor in its local feedback chain. It will be shown later that this is necessary to keep the servo stable. It may be regarded as a pure integrator in parallel with a D.C. amplifier of gain r/R_1.

When it is desired to obtain an equation governing the behaviour of a physical system we generally write down a differential equation using ordinary continuous differential coefficients. Having obtained such an equation the problem is how to solve it, and in many servo problems this may be very difficult. In this case it is only its values at certain instants of time that are of interest, to be exact, at the sampling instants. It is found, therefore, more convenient to handle if it is turned into a difference equation.

To do this differential coefficients are not needed, but instead finite differences. As the only interest now is in the value of $f(t)$ at the sampling instants, i.e., when $f(t) \rightarrow f(nT)$ n integral, $f(nT)$ will be written as f_n, divided differences will be used which are defined thus:

$$\Delta f_n = \frac{f_{n+1} - f_n}{T} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Hence:

$$f_{n+1} - f_n = T\Delta f_n \quad \ldots\ldots\ldots\ldots \quad (3)$$

* *R.R.D.E., Ministry of Supply.*

Therefore:

$$f_{n+1} = (1 + T\Delta)f_n \quad \ldots\ldots\ldots\ldots \quad (4)$$

Δf_n is analogous to the differential coefficient. If f_n is the set of values of a continuous function so that $f_n = f(nT)$ then:

$$L_{T/T \to 0}\, \Delta f_n = df/dt$$

THE CHARACTERISTIC EQUATION

An equation relating the quantities u_n and c_n will now be derived. It has already been seen that the correction is the quantity actually fed into the servo, or the quantity

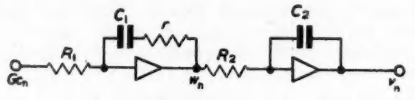


Fig. 2. Simplification of Fig. 1

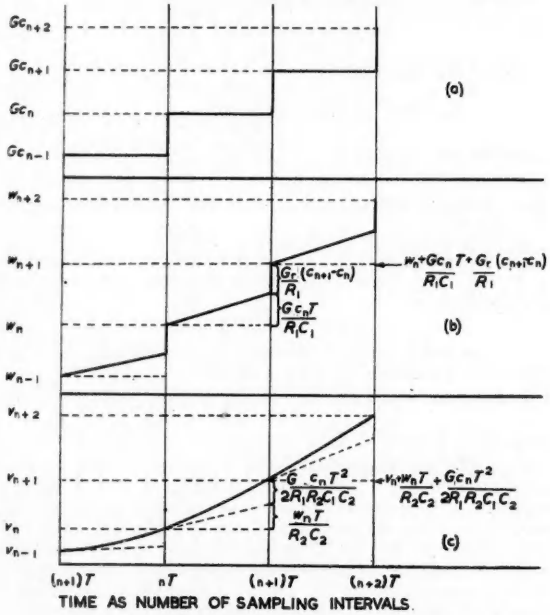


Fig. 3. Integration and amplification of error signal

which drives the servo, so that the circuit of Fig. 1 may be replaced by that of Fig. 2 and consideration given to what happens to the correction on passing through the two integrators. Fig. 3 shows the correction, the output and also the output from the first integrator w (as in Fig. 2) plotted against time as an integral number of sampling intervals.

The correction changes its value instantaneously at the sampling instant and then remains constant for T-sec. This change in the correction is immediately amplified through the first integrator, thus producing a step in w, shown dotted in Fig. 3(b) and this amplified correction is integrated in the final integrator to give the straight line shown dotted in Fig. 3(c). At the same time the new value of the correction is integrated in the first integrator to give the sloping line in Fig. 3(b). This integrated correction is now integrated again in the final integrator thus producing a squared term which gives a parabolic curve to the output.

It may be shown that if an integrator is fed with a step function input of E volts at a time $t = 0$, it will produce an output Et/RC. This applies also to the first integrator which we shall treat as an integrator in parallel with an amplifier of gain r/R_1.

Finally before obtaining the equation the gain in the discriminator circuit will be considered. Any RC circuit has a time-constant, whether it is being used as a differentiating circuit or an integrating circuit. Now if an amplifier be inserted the time-constant is effectively modified. This is equally true of a servo system which has its own natural period. In this case the gain will arise in the discriminator and sampling circuits, and we shall find that it effectively alters the natural period of the servo. This can be allowed for in the following manner.

Let the sampling mechanism have a voltage amplification factor G so that the input in Fig. 2 is Gc.

Let c_n be the correction at the n^{th} sampling instant and similarly u_n, v_n, w_n.

Suppose $f_n = L_T f(nT + \varepsilon)/\varepsilon \to +O$, so that any changes which take place instantaneously at the sampling intervals are supposed to have occurred before the measurement of f_n.

From Fig. 3(b) we see that:

$$w_{n+1} = w_n + Gr/R_1\,(c_{n+1} - c_n) + \frac{TGc_n}{R_1C_1} \quad \ldots\ldots\ldots \quad (5)$$

From Fig. 3(c) we see also that:

$$v_{n+1} = v_n + \frac{T}{R_2C_2} + 1/2\,\frac{T^2Gc_n}{R_1R_2C_1C_2}$$

But $v_{n+1} - v_n = T\Delta v_n$ from Equation (3)

Hence:

$$T\Delta v_n = \frac{T}{R_2C_2}w_n + 1/2\,\frac{T^2Gc_n}{R_1R_2C_1C_2} \quad \ldots\ldots \quad (6)$$

Similarly:

$$T\Delta v_{n+1} = \frac{Tw_{n+1}}{R_2C_2} + 1/2\,\frac{T^2Gc_{n+1}}{R_1R_2C_1C_2} \quad \ldots\ldots\ldots \quad (7)$$

Substituting for w_{n+1} in Equation (7) gives

$$T\Delta v_{n+1} = \frac{T}{R_2C_2}\left[w_n + Gr/R_1\,(c_{n+1} - c_n) + \frac{TGc_n}{R_1C_1}\right] + 1/2\,\frac{T^2Gc_{n+1}}{R_1R_2C_1C_2} \quad \ldots\ldots \quad (8)$$

Subtracting Equation (6) from Equation (8) gives

$$T(\Delta v_{n+1} - \Delta v_n) = \frac{TrG}{R_1R_2C_2}(c_{n+1} - c_n) + \frac{T^2Gc_n}{R_1R_2C_1C_2} + 1/2\,\frac{T^2G}{R_1R_2C_1C_2}(c_{n+1} - c_n)$$

Remembering $f_{n+1} - f_n = T\Delta f_n$ and $\Delta f_{n+1} - \Delta f_n = T\Delta^2 f_n$ we get

$$T^2\Delta^2 v_n = \frac{T^2rC_1G}{R_1R_2C_1C_2}\Delta c_n + \frac{T^2Gc_n}{R_1R_2C_1C_2} + 1/2\,\frac{T^3G}{R_1R_2C_1C_2}\Delta c_n$$

But $c_n = u_n - v_n$ from Equation (1)

$$\Delta^2 u_n = \Delta^2 c_n + \frac{G}{R_1R_2C_1C_2}(rC_1 + T/2)\,\Delta c_n + \frac{Gc_n}{R_1R_2C_1C_2}$$

Hence

$$\left[\Delta^2 + \frac{G}{R_1R_2C_1C_2}(rC_1 + T/2)\,\Delta + \frac{G}{R_1R_2C_1C_2}\right]c_n = \Delta^2 u_n \quad \ldots\ldots\ldots\ldots \quad (9)$$

It should also be noted that if $T \to O$, as $n \to \infty$, while $nT \to t$, the corresponding equation for the normal continuous case is:

$$\left[p^2 + \frac{rC_1Gp}{R_1R_2C_1C_2} + \frac{G}{R_1R_2C_1C_2}\right]c(t) = p^2\,u(t) \quad \ldots\ldots \quad (10)$$

SOLUTION OF DIFFERENTIAL EQUATION

This very familiar type of equation will be recognized as a simple second order differential equation whose solution is well known. The solution to Equation (10) consists of two parts. Firstly, the complementary function,

which is obtained by putting $u(t) = 0$.

$$c(t) = A \exp(\alpha t) + B \exp(\beta t) \quad \ldots\ldots (11)$$

α and β are the roots of the auxiliary equation, i.e.,

$$m^2 + \frac{rC_1G}{R_1R_2C_1C_2}\, m + \frac{G}{R_1R_2C_1C_2} = 0 \quad \ldots. (12)$$

and A and B are arbitrary constants which can only be determined from a knowledge of the boundary conditions. The correctness of this solution may be confirmed by substituting Equation (11) in Equation (10) with $u(t) = 0$. For a servo to be stable, the real parts of the roots must always be negative in which case these terms always damp out. As this solution is derived with $u(t) = 0$, it will be seen that these terms are always present whatever the nature of the function $u(t)$. As they are not permanent they are said to represent the transient behaviour of the servo and it will be shown later that the transient response is exceptionally important in the study of servo-mechanisms.

It will be remembered that α and β may be real, imaginary or complex. If they are complex they will, of course, be conjugate, and Equation (11) may easily be shown to be of the form:

$$c(t) = \exp(-bt)\,(A \cos \omega t + B \sin \omega t) \quad \ldots. (13)$$

where $\omega = \frac{\alpha - \beta}{2}$, and $b = \frac{\alpha + \beta}{2}$. This in turn may be rearranged to give $c(t) = \sqrt{(A^2+B^2)} \exp(-bt) \cos(\omega t + \phi)$ where ϕ is a phase-angle. It can be seen therefore that the transient response may be an exponentially damped sinusoidal oscillation. If the exponential term were ever positive the oscillations would be self sustaining, but as $b = \left[\frac{rC_1G}{2R_1R_2C_1C_2}\right]$, physical limitations prevent this.

Returning to Equation (10) the remaining part of the solution, known as the particular integral, is obtained by putting in the appropriate function for $u(t)$ and depends solely on this function. This solution is a permanent one and gives therefore the steady state behaviour of the servo. From this equation we can deduce the magnitudes of any steady-state errors or lags.

In an identical manner we find that the solution of Equation (9) also consists of two parts. This time, however, the complementary function, which is given by solving Equation (9) for $u_n = 0$, is found to be of the form:

$$c_n = A(1 + \alpha T)^n + B(1 + \beta T)^n \quad \ldots\ldots (14)$$

where α and β are the roots of the auxiliary equation. Letting $n \to \infty$, $T \to 0$, while $nT \to t$, Equation (14) becomes $c(t) = A \exp(\alpha t) + B \exp(\beta t)$, which is Equation (11).

The particular integral is again a function of the input, but we shall be concerned very little with it here as the general mathematical treatment is rather beyond this article. It will be seen that in the sampling case the values of α and β in Equation (14) again affect the nature of the transient response and this will be dealt with next.

Importance and Analysis of the Characteristic Equation

In the experimental study of servo-mechanisms there are two approaches which are particularly important. These are, the response to a step function and the response to a harmonic input. The latter is of great importance when one is concerned with the frequency characteristics. It has already been shown that whatever the nature of the input, the transient terms are always present in the output. For studying the transient response it is only necessary to provide some initial disturbance as an input. A step input provides this disturbance simply and satisfactorily.

The knowledge of the transient behaviour of a servo is of fundamental importance. Firstly, it tells whether the servo is stable. Secondly, it gives some indications as to how near or how far away from instability the servo is. It is rarely enough to know the servo is stable and will follow the input, it is generally required to know the manner in which it will follow. Thus, once the response to a step function is known, quite a lot can be deduced about the transient behaviour, e.g., if the servo's response to a step function were very lightly damped sine wave with a natural period of the order of seconds, then it would be of little practical use. This is because once the servo had been disturbed with an input it would take much too long to settle down ready to follow a further change in the input.

Complementary Function

The complementary function for both the sampling and continuous cases have been obtained. It will now be considered in rather more detail. As the continuous case is generally more familiar the cases will be considered side by side.

Continuous Case

The complementary function which was given in Equation (11) is:

$$c(t) = A \exp(\alpha t) + B \exp(\beta t) \quad \ldots\ldots (11)$$

where α and β are the roots of:

$$m^2 + \frac{rC_1Gm}{R_1R_2C_1C_2} + \frac{G}{R_1R_2C_1C_2} = 0 \quad \ldots\ldots (12)$$

This can be rewritten as:

$$m^2 + 2bm + C = 0 \quad \ldots\ldots (15)$$

The complementary function has three possible forms, if $b^2 > C$

$$c(t) = A \exp -(b + \sqrt{b^2 - C})t + B \exp -(b - \sqrt{b^2 - C})t \quad \ldots (16)$$

if $b^2 = C$, the roots of Equation (12) are coincident and the solution is:

$$c(t) = (A + Bt) \exp(-bt) \quad \ldots\ldots (17)$$

and finally if $b^2 < C$, the roots are complex and the complementary function may be written:

$$c(t) = \exp(-bt)\,[A \cos \sqrt{C - b^2}t + B \sin \sqrt{C - b^2}t] \quad \ldots (18)$$

Stability Limits—Continuous Case

It is obviously essential from a practical point of view that a servo should be stable. Therefore, it is necessary to know if there are any limits to the stability of the system, and if so, what they are. Considering Equations (16), (17) and (18) it can be seen that in each case there is a damping term $\exp(-bt)$ present, and it has been shown that b is always positive, i.e., the exponential term is always negative and thus the transient response always dies away exponentially. This article is primarily interested in the mathematical similarities and differences between continuous and sampling servos and it is for this reason that the mathematically stable region has been obtained. It must, however, be emphasized that mathematical and practical stability are not the same thing, and when designing a practically useful servo, other and more stringent criteria have to be used.

Nature of Transient Response—Continuous Case

The transient response as defined by Equations (16), (17) and (18) can now be considered. The roots of the auxiliary equation may be complex and conjugate, real and coincident, or real unequal and negative. They can never be real and positive. The solution given in Equation (18) represents a lightly damped sinusoidal response, which is said to be underdamped. (See Fig. 16(b).) When the roots are equal the response is no longer oscillatory and the servo is said to be critically damped. The initial overshoot is not followed by a further overshoot. Finally the damping is increased, the roots are unequal and the response is given by Equation (11) or (16). The initial response is now more rapid, but the overshoot is followed by a very slow aperiodic recovery. This condition is said to be overdamped. (Figs. 12(b)-13(b).)

To show how the nature of these responses depends upon

the values of R_1, R_2 C_1, C_2, and G the two time-constants $\sqrt{[(R_1R_2C_1C_2)/G]}$ and rC_1 have been plotted as x and y, respectively in Fig. 4. As shown previously, all physically real (i.e., positive) values of resistors and capacitors represent stable conditions so that the whole of the region shown in Fig.4 is mathematically stable. The line $rC_1 = 2\sqrt{[(R_1R_2C_1C_2)/G]}$ represents the condition for equal roots, i.e., $b^2 = C$. It will be shown later that plotting the same functions on a different scale gives the h-k plane. This plane presents very simply a great deal of fundamental information.

SAMPLING CASE

In this case, although the treatment and results are broadly similar to those of the continuous case, the stability limits are more stringent and the responses more varied.

Again, starting by considering the auxiliary equation:

$$m^2 + \frac{G}{R_1R_2C_1C_2}(rC_1 + T/2)\,m + \frac{G}{R_1R_2C_1C_2} = 0 \quad \ldots\ldots\ldots\ldots\ldots (19)$$

For convenience let $rC_1/T = k$, and $\sqrt{(R_1R_2C_1C_2/T\sqrt{G}} = h$, Equation (19) now becomes:

$$m^2 + 1/h^2T\,(k + 1/2)m + 1/h^2T^2 = 0 \quad \ldots\ldots (20)$$

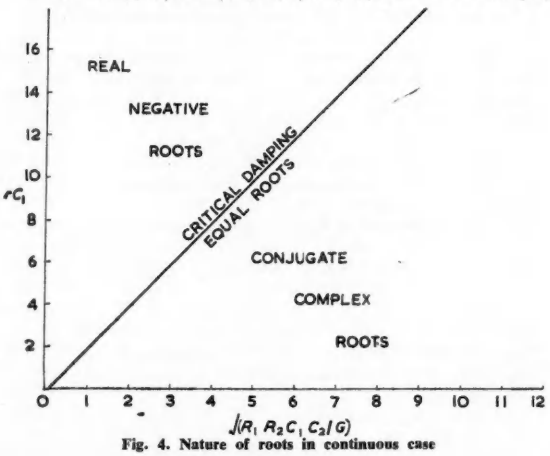


Fig. 4. Nature of roots in continuous case

The complementary function is:

$$c_n = A(1 + \alpha T)^n + B(1 + \beta T)^n \quad \ldots\ldots\ldots (14)$$

where α and β are the roots of Equation (19) or (20).

It has been seen previously that the transient response depends upon the nature of these roots. The roots in turn depend upon the coefficients of Equation (20). Thus we see that the relationship between h and k determines the roots and the roots in turn determine the nature of the transient response. These parameters turn out to be extremely important in the study of this servo and it is found very convenient to plot k against h. From the position in the h-k plane of any similar second order sampling servo, its transient behaviour and indeed other characteristics such as its ability to deal with a noisy input can be estimated immediately.

STABILITY LIMITS. SAMPLING CASE

The roots of the auxiliary equations are α and β. But Equation (14), for example, shows that αT and βT are of less interest $(1 + \alpha T)$ and $(1 + \beta T)$. For clarity of treatment $(1 + \alpha T)$ will be used, not αT. From now on $(1 + \alpha T)$ or $(1 + \beta T)$ will be referred to as the "bracket".

To determine the stability limits consider the responses of the system. Again the roots may be complex conjugates or real. When $4h^2 > (k + 1/2)^2$ the roots and hence the brackets are complex and the complementary function may be written:

$$c_n = R^n(A\cos n\theta + B\sin n\theta) \quad \ldots\ldots\ldots (21)$$

If this is to be stable it is necessary that $c_{n+1} < c_n$ (i.e., the terms are dying away). This can only be so if $R^{n+1} < R^n$, which means that the magnitude of $R < 1$. To satisfy this condition we find that $k > 1/2$. This defines one stability limit (see Fig. 5).

When $(k + \frac{1}{2})^2 > 4h^2$ the roots and the brackets are always real, but the brackets are not necessarily of the same sign. This apparently simple statement covers an intrinsic property of sampling servos which is fundamentally and completely different from any behaviour of the continuous case. As this may be somewhat unfamiliar to most readers it will be considered in detail.

It has just been stated that the roots and brackets are always real (in this part of the h-k plane). αT cannot be positive so it is only necessary to consider negative values. Consider $f_n = (1 + \alpha T)^n$. Firstly when αT lies between 0 and -1, e.g. let $\alpha T = -\frac{1}{2}$. If $n = 0,1,2,3, \ldots f_n = +1, +\frac{1}{2}, +\frac{1}{4}, +\frac{1}{8}, + \ldots$. It is seen immediately that f_n is dying away in a manner closely resembling an exponential decay.

Now consider the same function when αT lies between -1 and -2, e.g. let $\alpha T = -1\frac{1}{2}$. Again, for $n = 0,1,2,3, \ldots f_n = +1, -\frac{1}{2}, +\frac{1}{4}, -\frac{1}{8}, + \ldots$ (see Fig. 9(a)). Here

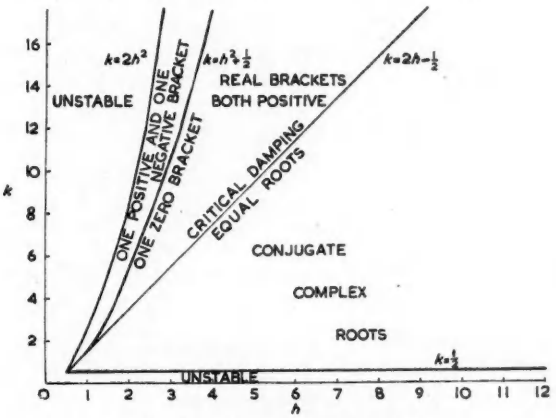


Fig. 5. Map of h-k plane in sampling case

may be seen the difference from the continuous case because the response has become oscillatory—without complex roots. This has no counterpart in the continuous case. Note that the oscillations are damped out and so the servo is still stable.

Finally, consider the case when αT is numerically greater than 2, and negative, e.g. $\alpha T = -2\frac{1}{2}$. The corresponding values for f_n are now $1, -3/2, +9/4, -27/8, + \ldots$. The response is again oscillatory, but $f_{n+1} > f_n$, or in other words the oscillations are building up and the servo is no longer stable. The condition for stability here is that $k < 2h^2$ so that the h-k plane is now bounded by the line $k = \frac{1}{2}$, and the parabola $k = 2h^2$. Inside this region the servo will be stable, outside it will be unstable.

NATURE OF TRANSIENT RESPONSE

Now having found which parts of the h-k plane may be used if the servo is to be stable, the nature of the actual transient responses can be considered.

The first and main division of the h-k plane is that between real and complex roots. This is given by the line $k = 2h - \frac{1}{2}$, when $k < 2h - \frac{1}{2}$, the roots and hence the brackets are complex and the equation may be written as

$$c_n = R^n(A\cos n\theta + B\sin n\theta) \quad \ldots\ldots\ldots (21)$$

which represents an oscillation which is almost but not quite sinusoidal (Fig. 16(a)). θ, it should be noted, is a

function of h and k and hence T. The natural period of oscillation is approximately $2\pi hT$.

k mainly influences the damping term, and the damping steadily increases until $k = 2h - \frac{1}{2}$, when the roots are equal and by analogy with the continuous case, may be described as critically damped.

The equation is now

$$c_n = (A + Bn)(1 + \alpha T)^n \quad \ldots\ldots\ldots\ldots (22)$$

$\alpha = \beta$, and both brackets are real, equal and positive. The response now consists of an overshoot followed by an aperiodic recovery. Finally $(1 + \alpha T)$ cannot be greater than unity.

The final division of the h-k plane is the parabola $k = h^2 + \frac{1}{2}$. When $k < h^2 + \frac{1}{2}$ (and $k > 2h - \frac{1}{2}$) the complementary function is

$$c_n = A(1 + \alpha T)^n + B(1 + \beta T)^n \quad \ldots\ldots\ldots\ldots (14)$$

In this case both the brackets are real, positive and less than unity, hence they damp out. The response is overdamped and consists of a slight overshoot followed by a slow aperiodic recovery.

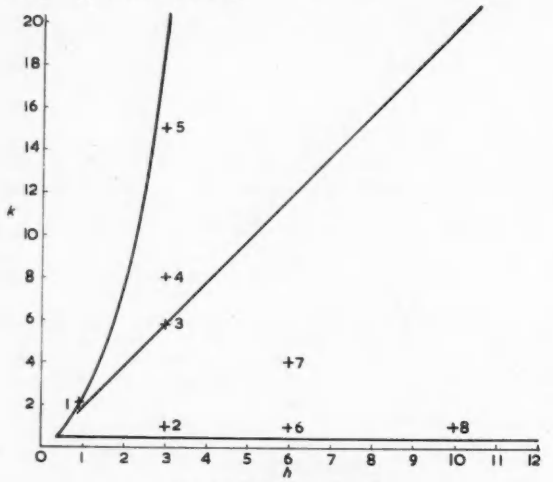


Fig. 6. Position of responses

When $k = h^2 + \frac{1}{2}$, one bracket is zero and the other remains positive. This is in effect the limiting case of the overdamped response.

Finally when $k > h^2 + \frac{1}{2}$ (and less than $2h^2$ for stability) the complementary function is again

$$c_n = A(1 + \alpha T)^n + B(1 + \beta T)^n$$

but here one bracket is negative, the other remaining positive. This produces an oscillatory waveform. This waveform is approximately triangular and has a constant period $= 2T$ (Fig. 9(a)). While the magnitude of $(1 + \alpha T)$ is less than unity, the oscillations die away almost exponentially until finally $k > 2h^2$ and the oscillations are sustained.

The h-k plane is given in Fig. 5 with the divisions marked. For all the foregoing conditions to be true, $h > 1$. When h is less than unity, somewhat different conditions exist as the servo is fringing on two unstable regions with different modes of oscillations.

Physical Interpretation of Responses Demonstrated

In this section responses shown in Figs. 9(a)-16(a) will be considered and an attempt made to interpret them physically. The oscillographs show some typical responses which have been obtained experimentally.

In every case the top left shows the step input, and immediately below it the *error*. The top right shows the resultant output and underneath it is the rate. It should be noted that the bottom left-hand tube displays the error and not the correction. This does not affect the principle involved. However, from the mathematical point of view of the theory it is perhaps unfortunate, e.g., see below where the sinusoidal type or response is discussed. To obtain the correction it is necessary only to imagine the mirror image about the X axis, i.e. anything positive becomes negative and vice versa.

As mentioned above, these are experimental results displayed on four C.R.T. operated by a common single stroke time-base. Thus for any particular response the time scale is the same on all four tubes. The Y-plate sensitivities may vary due to tolerances in the amplifiers feeding the C.R.T. The experimental model worked on the mains frequency, i.e. $T = 1/50$sec, so that by counting the errors it is possible to assess the speed of a particular response except in the sinusoidal case when the separate errors cannot be distinguished.

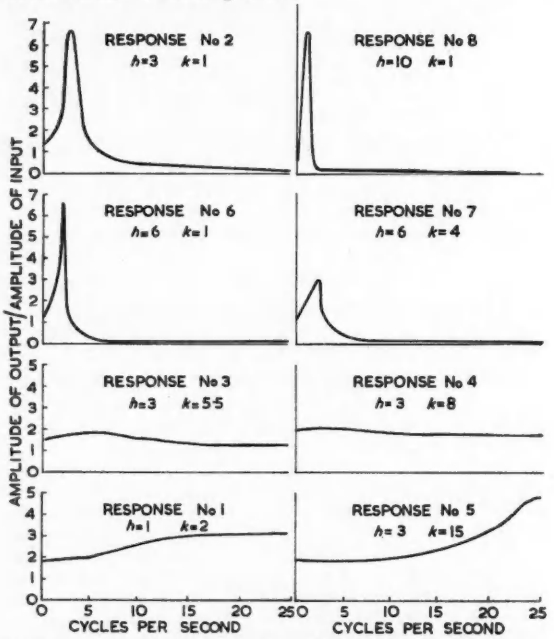


Fig. 7. Frequency characteristics of sampling servo corresponding to step responses in Figs. 9(a) to 16(a)

For interest, Figs. 9(b)-16(b) show the corresponding responses when the sampling mechanism is removed and the servo becomes continuously operated. It will be seen from Figs. 4 and 5 that the response which corresponds to coincident roots in the sampling case, i.e. $k = 2h - \frac{1}{2}$, Fig. 5 will not correspond exactly to coincident roots in the continuous case, i.e. $rC_1 = 2\sqrt{(R_1R_2C_1C_2/G)}$ (Fig. 4). For each pair of cases, however, the circuit parameters are identical, e.g. Figs. 9(a) and 9(b) are absolutely identical except for presence and absence of the sampling mechanisms. The position of these actual experimental results in the h-k plane are shown in Fig. 6.

Responses 2, 6 and 8, Figs. 10(a), 14(a), 16(a) all represent $k = 1$, i.e. they are comfortably inside the stability limit, and are in the complex part of the h-k plane (Fig. 6) and are therefore almost sinusoidal. It will be seen at once that as h increases the damping decreases. At the same time—although not so easily apparent—the period is increasing. This may be seen if the error is closely examined in responses 2 and 8, in response 2 it is easily seen to consist of discontinuities, in response 8 it appears to be continuous owing to the fact that the time-base has been slowed down. Looking at the original servo Fig. 2 for a moment it can be seen that k small means r small

and it can therefore be ignored. The servo now consists of two perfect integrators and hence the correction is being doubly integrated and, owing to the absence of a direct path through the first integrator, there are no discontinuities and the output is a smooth second order curve.

A cosine is being integrated to give a sine, which in turn is being integrated to give minus a cosine. This means that the output is lagging behind the rate by 90°. Similarly, the rate is lagging behind the correction by 90°, so that the output is lagging behind the correction by 180°. But as mentioned at the beginning of this section, the oscillograph actually shows the error which in turn is 180° out of phase with the correction and is thus in phase with the output. If two photographs are examined, the error and output will be seen to be in phase and the rate 90° out of phase. Response 7 shows h the same as in response 6, i.e. $h = 6$, but k is now 4 as against 1 (Fig. 15(a)). It will be seen that the damping has increased considerably, but the period (allowing for the time-base) is approximately the same. Examination of the rate will show that amplification is still slight.

If we return to response 2, and then on to number 3, we see the effect of increasing k. This has increased the damping so that the response is no longer oscillatory but is "critically damped" (equal roots). It will be seen to consist of a single overshoot followed by a gentle aperiodic recovery. Looking at the rate we see that the correction is being amplified considerably. As a result the output appears to be made up of straight segments, although in fact there must always be a second order effect present. A further increase in k gives response 4, now both brackets are positive and unequal. This response, which is over-damped and very similar to the continuous case, is similar to number 3. The amplification is slightly more pronounced, the output is not quite so smooth, but the transient is slightly quicker.

Finally, increasing k still further gives response 5 which shows the triangular waveform corresponding to one negative root. Referring again to Fig. 2 and bearing in mind that the first integrator is equivalent to an integrator in parallel with a D.C. amplifier, it can be seen that r is now so large that the amplifying properties of the first integrator have largely swamped its integrating properties. In consequence, the servo approximates to a D.C. amplifier followed by an integrator. If the rate is examined this will be clearly seen. It is for this reason that the output looks at a first glance to be made up of linear elements. Looking closely it can be observed that they are still slightly curved. This must be so as a contribution from the integrator is always present. What is happening therefore is that correction is being amplified, and this amplified correction is so large that it over-drives the servo output, thus producing another correction of the opposite sign. This process keeps being repeated. And in fact, when the amplification is sufficiently large, the corrections never die away and the servo goes on oscillating. This over-correction is a characteristic of sampling servos and has no counterpart in the continuous case. Response 1 shows the same case, but slightly nearer the stability boundary showing the near exponential decay.

Velocity and Accelerating Inputs

It has been stated $\Delta f_n = \dfrac{f_{n+1} - f_n}{T}$ ..... (2)

from which it follows that

$$\Delta^2 fn = \frac{\Delta f_{n+1} - \Delta f_n}{T}$$

$$= \left(\frac{f_{n+2} - f_{n+1}}{T} - \frac{f_{n+1} - f_n}{T} \right) \Big/ T$$

$$= \frac{(f_{n+2} - 2f_{n+1} + f_n)}{T^2} \quad \ldots\ldots\ldots\ldots\ldots (23)$$

And the characteristic equation of the servo was obtained.

$$\left[\Delta^2 + \frac{G}{R_1R_2C_1C_2}(rC_1 + T/2\Delta + \frac{G}{R_1R_2C_1C_2} \right]$$

$$c_n = \Delta^2 u_n \quad \ldots\ldots\ldots\ldots\ldots (9)$$

With the aid of these two equations the manner in which the servo follow an input which contains first or second derivations of position can be considered which is of considerable importance in servos. It has already been shown that the servo does in fact follow a step function without permanent error. This can be confirmed quite simply by considering the right-hand side of Equation (9).

It is obvious that a step function has no first difference and no second difference (except at $t = 0$). Hence Equation (23) gives zero for the right-hand side, which is the equation we have already met and solved as the complementary function. We have found this contains no permanent terms.

Velocity Input

In a similar manner we consider a velocity input function,

$$u_n = Vt = VnT$$
$$u_n = VnT$$
$$u_{n+1} = V(n + 1)T$$
$$u_{n+2} = V(n + 2)T$$

Substituting in Equation (23) gives

$$\Delta^2 u_n = VT/T^2[n + 2 - 2(n + 1) + n] = 0$$

Again the correction is zero, as $n \to \infty$, $V_n \to u_n$.

Accelerating Inputs

To find the error in the case of the accelerating input

let $u_n = \frac{1}{2}at^2 = \frac{1}{2}a(nT)^2$
$u_n = \frac{1}{2}a(nT)^2$
$u_{n+1} = \frac{1}{2}a(nT + 1)^2$
$u_{n+2} = \frac{1}{2}a(nT + 2)^2$

So that $\Delta^2 u_n = a/2T^2\ [(n + 2)^2 - 2(n + 1)^2 + n^2]\ T^2 = a$

Substituting in Equation (9) we get

$$\left[\Delta^2 + \frac{G}{R_1R_2C_1C_2}(rC_1 + T/2)\Delta + \frac{G}{R_1R_2C_1C_2} \right] c_n = a$$

$$c_n = a \cdot \frac{1}{\Delta^2 + \dfrac{G(rC_1 + T/2)\Delta}{R_1R_2C_1C_2} + \dfrac{G}{R_1R_2C_1C_2}}$$

Noting Δa and $\Delta a^2 = 0$

$$c_n = R_1R_2C_1C_2\ a/G \quad \ldots\ldots\ldots\ldots (24)$$

The correction is now proportional to the acceleration and proportional to the effective time constant of the servo squared. Finally by putting $v_n = u_n - c_n$ as $n \to \infty$

$$v_n = u_n - \frac{R_1R_2C_1C_2}{G}\ a$$

This is now a steady state error as distinct from the transient errors already dealt with. In this case it will be seen that the output will always lag behind the input and these errors are called lags.

This is of course the normal behaviour for a second order servo; position and velocity inputs are followed without error, any inputs containing accelerations or changes of accelerations are only followed with errors.

The Harmonic Response

In the continuous case a sinusoidal oscillation is fed in, the frequency varied and the ratio of the output and input amplitudes measured, in addition the phase lag may be measured. The frequency of the output is the same as that of the input.

In the sampling case the situation is not so straightforward. The servo only sees the input sine wave once every T seconds. Sine waves are of course periodic and hence if any two sine waves have the same values at the instants corresponding to the sampling instants, then the

servo will be unable to differentiate between them. Actually all sine waves of the form

$$\exp\left[i\left(\frac{2\pi m \pm \omega_0}{T}\right)t\right]$$

(m-integral) have the same values at the sampling instants, so that the servo presented with a wave of frequency $\left(\frac{2\pi m \pm \omega_0}{T}\right)/2\pi$ will imagine that it is receiving a wave of frequency $\omega_0/2\pi$.

This in turn leads to a second difference, it has been stated that in the continuous case, if the input is sinusoidal then so is the output. In the sampling case this is no longer true. If the input is a sine wave the sampled points lie on a sine wave and the output at the sampling instants also lie on a sine wave but the continuous output wave will not be sinusoidal.

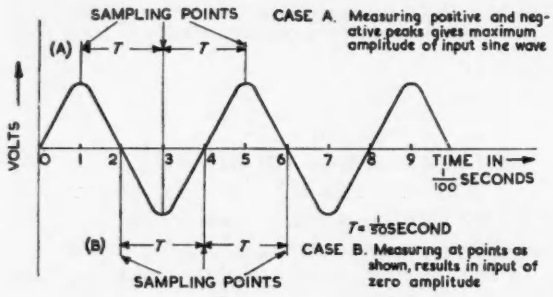

SAMPLING POINTS
CASE A. Measuring positive and negative peaks gives maximum amplitude of input sine wave
(A)
T
T
VOLTS
0 1 2 3 4 5 6 7 8 9 TIME IN
1/100 SECONDS
T = 1/50 SECOND
(B)
T
T
CASE B. Measuring at points as shown, results in input of zero amplitude
SAMPLING POINTS

Fig. 8. The importance of the phase in sampling a sine wave

An example may make this clear (Fig. 8). Assume a servo with a sampling frequency of 50 times per second, and an input sine wave of frequency 25c/s. If the servo samples the sine wave when the phase-angle of the latter is 90°, it will next sample 1/50sec later, i.e. corresponding to a phase angle of 270°. This means that the servo is sampling the positive and negative peaks, so that the output will be an almost triangular waveform. Again, should the sampling take place at the intervals corresponding to 0° and 180°, then the output of the servo will be zero. In between these extremes there are, of course, a series of intermediate values for the apparent amplitude of the input sine wave. The foregoing remarks should be sufficient to emphasise that "frequency response" used in the case of the sampling servo is very different from the meaning ascribed to it in the continuous case. Any problem involving frequency response needs very careful consideration therefore.

The frequency amplitude characteristics have been measured experimentally using a low frequency oscillator. This was done using an oscilloscope and measuring the quantity $\frac{\text{amplitude of output.}}{\text{amplitude of input.}}$ The peak-to-peak amplitude of the input, a sine wave, is easily obtained, the amplitude of the output was taken as being the difference between the most positive and the most negative level obtained with a given frequency as the phase at which it was sampled varied. This will be understood if one thinks for the moment of the example of the 25c/s wave given above.

To obtain the complete response it is only necessary to vary the input from 0-25c/s. From 25-50c/s the response curve represents a mirror image and after this it is periodic every 50c/s. The frequency response curves have been measured for the same circuit parameters that have already been considered in the photographs. These are shown in Fig. 7. It will be noted that where the system has a natural "sinusoidal" frequency the usual resonance phenomenon occurs. When the transient response is triangular, the amplitude increases rapidly in the region of the frequency of oscillation ($1/2T = 25$c/s). Where the transient response is aperiodic the amplitude is fairly even.

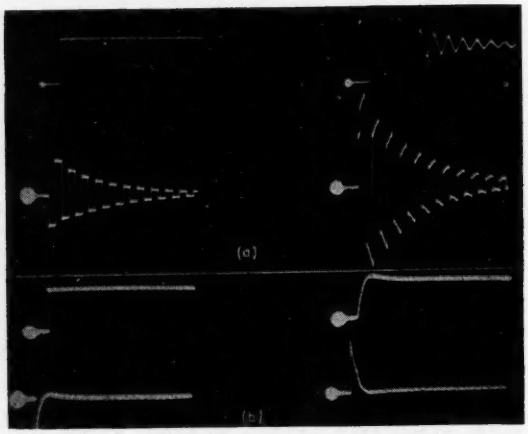


Fig. 9(a). Response No. 1. Sampling case
Fig. 9(b). Response No. 1. Continuous case

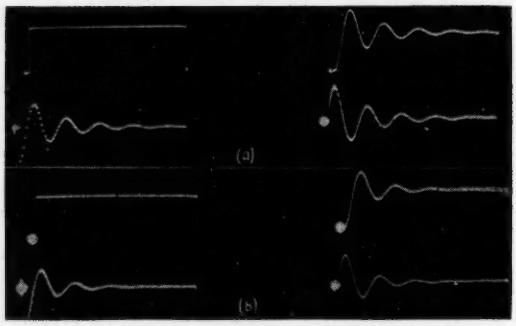


Fig. 10(a). Response No. 2. Sampling case
Fig. 10(b). Response No. 2. Continuous case

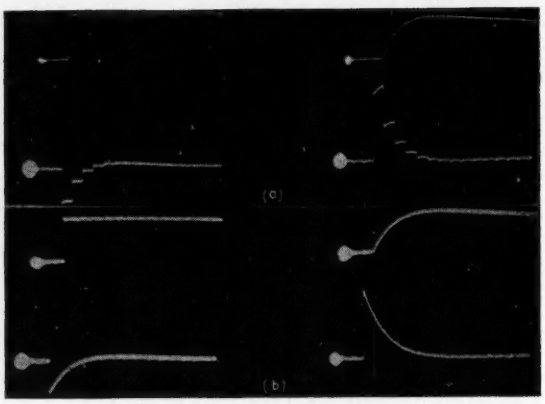


Fig. 11(a). Response No. 3. Sampling case
Fig. 11(b). Response No. 3. Continuous case

Conclusion

A simple second-order electronic servo being fed with sampled data has been considered. This type of servo

is of interest because of its increasing use and rather different behaviour from the more usual continuous servo. The characteristic equation has been obtained and solved for a number of inputs. The complementary function has been solved and the transient response examined in some detail. In addition oscillographs of the main responses to a step fuction are given for a sampling servo. Its harmonic response has been experimentally determined.

It has been found that the servo is unstable if there is insufficient damping. Similarly if it is too damped it is

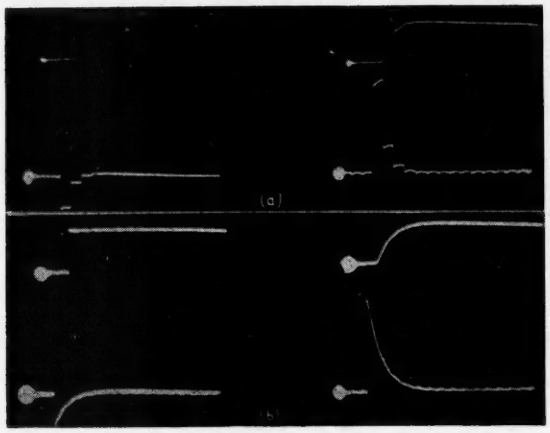


Fig. 12(a). Response No. 4. Sampling case
Fig. 12(b). Response No. 4. Continuous case

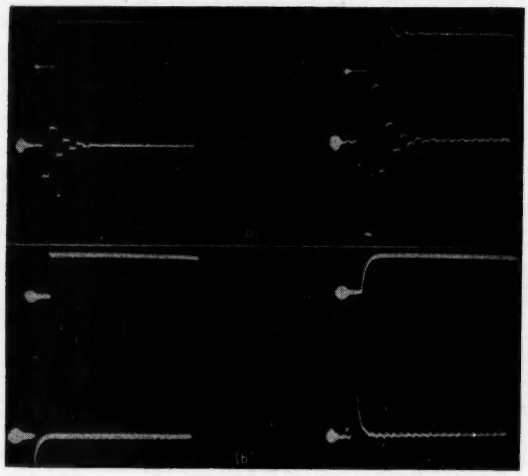


Fig. 13(a). Response No. 5. Sampling case
Fig. 13(b). Response No. 5. Continuous case

again unstable, but this time the oscillation is triangular instead of almost sinusoidal. This in turn leads to more variety in the transient responses. If the sampling frequency is very rapid and the damping is sufficient the behaviour approximates to that of the continuous case.

The servo takes a sampled and therefore discontinuous data and produces an apparently smooth although actually discontinuities in the change of curvature are present. Like its continuous counterpart it follows a step or velocity input without error but lags behind accelerating and higher-order inputs.

When the servo is fed with a sinusoidal input the output is not sinusoidal. The servo is quite unable to differentiate between any waves of pulsatance $\left(\frac{2\pi m}{T} \pm \omega_0\right)$ and its response repeats every $1/Tc/s$.

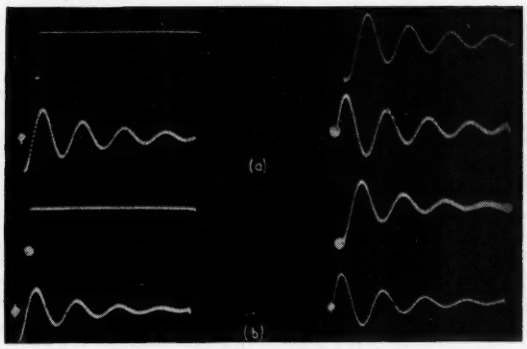


Fig. 14(a). Response No. 6. Sampling case
Fig. 14(b). Response No. 6. Continuous case

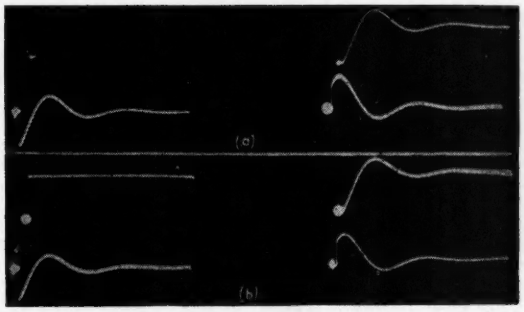


Fig. 15(a). Response No. 7. Sampling case
Fig. 15(b). Response No. 7. Continuous case

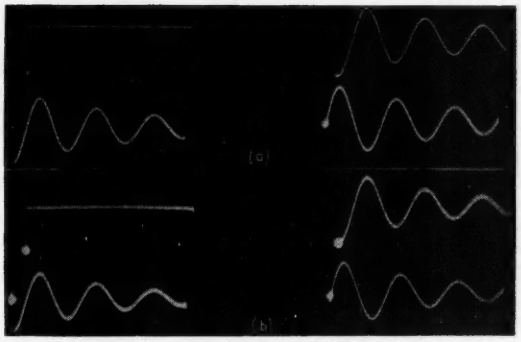


Fig. 16(a). Response No. 8. Sampling case
Fig. 16(b). Response No. 8. Continuous case

Acknowledgments

The author would like to express his thanks to Mr. A. E. Bailey for his help and encouragement and also to the Chief Scientist, Ministry of Supply, for permission to publish this article. Crown copyright reserved. Reproduced by permission of the Controller, H.M. Stationery Office.

REFERENCE

[1] Holt-Smith, C., Lawden, D., Bailey, A. E. Characteristics of Sampling Servo Systems. Automatic and Manual Control. (Butterworth, 1952.)

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

Measurement of Amplitude Distortion in D.C. Amplifiers

DEAR SIR,—It may not be realized by users of D.C. amplifiers that the well known intermodulation method of testing for amplitude distortion may be modified to yield a quick and simple way of assessing the linearity of D.C. amplifiers.

In place of the two frequencies used in the intermodulation method, a small alternating signal of constant amplitude, and a steady or D.C. signal which may be varied from zero to the full handling capacity of the system are fed together into the amplifier. The method consists of simply measuring the amplitude of the alternating signal at the output of the amplifier for a number of different values of the D.C. signal. The variation of sensitivity of the amplifier is thus determined at points over the working range.

The amplifiers tested in this laboratory were fed with a 1 000c/s signal, and a D.C. signal from a small battery and potentiometer arrangement. The output was measured by means of a rectifier valve-voltmeter designed to deal with both single-sided and push-pull outputs. Fig. 1 shows the circuit of the valve-voltmeter.

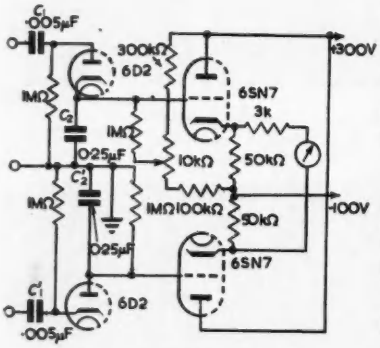


Fig. 1. Circuit of the valve-voltmeter

The 1 000c/s output is rectified by the diodes and fed to the grids of the 6SN7 double triode arranged as a cathode-follower. After adjustment the microammeter gives a reading which is a measure of the sensitivity of the amplifier, and by altering the D.C. input, the variation of sensitivity over the working range may be read off.

Should the amplifier under test have a push-pull output, the capacitors C_1, C_2, C_1' and C_2' must be matched so that

$$\frac{C_1}{C_1+C_2} = \frac{C_1'}{C_1'+C_2'}$$

in order to feed the cathode-followers with inputs which are identical fractions of the two outputs from the amplifier.

The use of the cathode-followers ensures that the effect of any difference in the response of the two halves of the 6SN7 is reduced to a minimum. Such precautions are necessary as the linearity of the two sides of a push-pull amplifier may differ, and for accurate measurement it is important that each should contribute correctly to the reading of the microammeter.

The main advantage of the method lies in its simplicity and ease of operation. The shape of the output-input curve is not obtained directly, but if required may be calculated provided sufficient values of its slope are taken.

Yours faithfully,

W. G. P. LAMB,
Ministry of Supply.
A.W.R.E.

Direct Reading Thermistor Bridge

DEAR SIR,—In their excellent article on the design of a direct reading thermistor bridge in the February, 1953, issue of ELECTRONIC ENGINEERING, Messrs. Pearson and Benson mention that the resistance law for bead type thermistors holds over a range from zero frequency to 10 000Mc/s. I believe that I am correct in stating that careful experiments have shown that the error is about 8 per cent at 10 000Mc/s and about 2-3 per cent at 3 000Mc/s, the error being in that direction which would give a low power reading on the bridge. The small amount of power that is lost is presumably dissipated largely in the glass envelope of the thermistor.

On the question of zero compensation and sensitivity compensation, I have adopted the decade resistance box method mentioned but have found it advantageous actually to perform a separate calibration of the chosen disk thermistors, and then to calculate, as shown below, the values of compensating shunt resistors and series resistors from the equation that I derived for this purpose.

I have found that the S.T.C. type KB5251/80 and KB2231/80 are the most suitable for zero and sensitivity compensation respectively and although the method adopted gives only 2-point matching in each case I have observed, for zero compensation at least, an accuracy of better than 0·1 per cent per degree C between 0°C and +40°C. It is difficult to measure the resulting accuracy of sensitivity compensation due to small variations in R.F. power.

Fig. A shows a similar arrangement of the bridge network to that in the article.

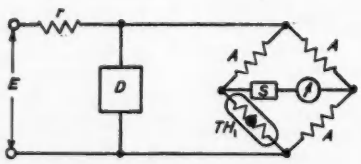


Fig. A. Bridge network arrangement

D and *S* are decade resistance boxes and for the zero compensation, the R.F. mount containing TH_1 is, enclosed in a suitable container, the temperature of which is varied over the range required. *S* is adjusted to give reasonable sensitivity and *D* is set say every 5°C to give balance. A curve is drawn of *D* against temperature. Resistance *r* is maintained at 3 500 ohms. From the curve obtained, the average slope of the resistance/temperature curve may be read. This is known as the mean required slope = α ohms/°C.

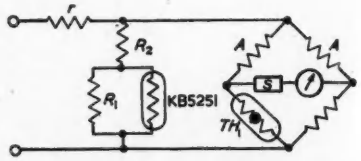


Fig. B. Average difference of resistance between curves over required temperature range

The KB5251 thermistor is calibrated by immersion in transformer oil, varying the temperature over the required range and noting the resistance value, as measured by a Wheatstone Bridge, say every 5°C. A curve of this is drawn and the value of the KB5251 resistance at two suitable points in the temperature range is read. For normal thermistor bridges, temperatures of 10°C and 30°C would be suitable. Let the two resistance values obtained be *a* ohms and *b* ohms with *a* the higher value, and let *t* be the temperature range. It will be noticed that the slope of the KB5251 thermistor in ohms/°C is much higher than the mean required slope, therefore by shunting the KB5251 with a suitable value of resistor, R_1 ohms, the two slopes can be made approximately parallel. From the data above, R_1 can be calculated from the following quadratic equation:—

$$R_1^2\,(a\text{-}b\text{-}\alpha t) - R_1\,\alpha t\,(a+b) - \alpha t a b = 0.$$

Typical values are as follows:—

α = 5·2 ohms/°C.
a at 10°C = 840 ohms.
b at 30°C = 340 ohms
t = 20°C

Then R_1 = 477 ohms.
i.e.

The chosen KB5251 thermistor when shunted with 477 ohms will give the mean required slope of 5·2 ohms/°C at least between the range of 10°C to 30°C. The slope of the combined KB5251 and its shunt resistor can now be plotted on the same graph as the mean required slope. The two curves will be seen to be approximately parallel, the KB5251 plus shunt resistor being at the lower

resistance value. The average difference of resistance between the curves over the required temperature range represents the series resistance R_2 that is needed. (See Fig. B).

Wire wound potentiometers may be used and their values set up by means of a Wheatstone Bridge and they can then be locked.

Similar methods can be used for evaluating the sensitivity compensation network *S*, the values being calculated in the same way. In this case, of course, a stable source of R.F. power is required.

This method has been so successful that test runs, after setting up as above, have shown no chance of obtaining any improvement in temperature compensation by further adjustment of R_1 or R_2.

In regard to bridge sensitivity, I have found the D.C. method of measuring bridge current at balance with no R.F., then bridge current at balance with R.F. and then calculating the value of applied R.F. (which gave some known meter deflexion) to be quite satisfactory. By using a double coil meter of high sensitivity which is shunted to measure initial bridge current, then backed off by current through the second coil, shunt removed and movement reversed (owing to the fact that the second current is lower than the first) it is possible to measure quite accurately the change of bridge current in the presence of the initial standing current.

Yours faithfully,

K. F. TREEN,

Whetstone,

London, N.20.

The authors reply:

DEAR SIR,—We thank Mr. Treen for his interesting letter and we note that using a graphical method of matching he has been successful in temperature compensating a thermistor bridge using KB5251/80 and KB2231/80 disks.

With regard to the first paragraph of his letter the operation of bead-thermistor bridges (balanced or direct-reading) for the measurement of microwave power depends on the premise that *P* watts of microwave power produces the same change in bead resistance as *P* watts of D.C. power. In the same way as other workers we have accepted this as being true. Up to the time of designing the bridge (nearly three years ago) and writing the article, the only work tending to disprove this seemed to be that of Reference 2 of the article. This states that a thermistor bridge was checked against the accepted fundamental method of measuring microwave power, namely the water calorimeter. Errors of a few per cent were observed at wavelengths around 3cm, large errors were found in the millimetre range of wavelengths but no figures were given for errors, if any, at wavelengths near 10cm.

It may be that other investigations have been carried out on this topic in the last two years. In fact, Mr. Treen's letter suggests that careful measurements have now been made, possibly by himself. We should be pleased and very interested to have references to, or details of such work.

From Mr. Treen's comments the KB5251/80 disk thermistors seem to be easier to match than the KB420 type for zero-drift compensation. His method of calibrating the disk and using a figure for "mean required slope" should work very well when the resistance/temperature curve to be matched is fairly straight. Much more variation of the shape of the matching-network characteristic is possible when three resistors are used but this is not always necessary.

In connexion with checking the sensitivity compensation practically (paragraph 3 of Mr. Treen's letter) a klystron as a source of microwave power is as stable as its power supplies and a short fixed probe coupled through a crystal rectifier to a microammeter should give a fairly accurate indication as to when the power delivery down the guide is stable. Continuous monitoring of the bridge supply voltage *E* is also necessary.

A double-coil meter, as suggested, is an ideal means of measuring the change of bridge current in a balanced thermistor bridge.

Yours faithfully,

R. M. PEARSON,

F. A. BENSON,

Department of Electrical Engineering, University of Sheffield.

The Fourpole Transmission Matrix

DEAR SIR,—The fourpole transmission matrix derived by Mr. W. R. Hinton in his paper "The Measurement of '*A*' Matrix Elements of Passive Networks" which appeared in the April issue is readily obtained by the elementary operations of fourpole matrix theory.

The six Strecker-Feldtkeller fourpole equations are so related that any transformation matrix may be expressed in terms of the elements from any of the other five. Mr. Hinton's derivative is merely an expression of the transmission matrix in terms of elements selected from the mutually inverse immittance matrices

$$\mathbf{Z}=\begin{pmatrix} z_{11} & z_{12} \\ -z_{12} & z_{22} \end{pmatrix}=\frac{1}{\det \mathbf{Y}}\begin{pmatrix} y_{22} & -y_{12} \\ y_{12} & y_{11} \end{pmatrix} \quad \ldots\ldots (1)$$

$$\text{and } \mathbf{Y}=\begin{pmatrix} y_{11} & y_{12} \\ -y_{12} & y_{22} \end{pmatrix}=\frac{1}{\det \mathbf{Z}}\begin{pmatrix} z_{22} & -z_{12} \\ z_{12} & z_{11} \end{pmatrix} \quad \ldots\ldots (2)$$

where, in his notation,

$$z_{11}\equiv Z_{OCP};\ z_{22}\equiv -Z_{OCQ};\ y_{11}\equiv 1/Z_{SCP};\ y_{22}\equiv -1/Z_{SCQ} \quad \ldots\ldots (3)$$

Equating elements on the principal diagonals in (2) gives

$$\det \mathbf{Z}=z_{11}z_{22}+z_{12}^2=z_{22}/y_{11} \text{ or } z_{11}/y_{22} \quad \ldots\ldots (4)$$

from which

$$z_{12}=\pm\sqrt{[z_{22}(1/y_{11}-z_{11})]} \text{ or } \pm\sqrt{[z_{11}(1/y_{22}-z_{22})]} \quad \ldots\ldots (5)$$

The transmission matrix in terms of the elements of **Z** is

$$\mathbf{A}=-\frac{1}{z_{12}}\begin{pmatrix} z_{11} & -\det \mathbf{Z} \\ 1 & -z_{22} \end{pmatrix} \quad \ldots\ldots (6)$$

which, substituting from (4) and (5), may be written

$$\mathbf{A}=\frac{\pm}{\sqrt{[z_{22}(1/y_{11}-z_{11})]}}\begin{pmatrix} z_{11} & -z_{22}/y_{11} \\ 1 & -z_{22} \end{pmatrix}$$

or

$$\frac{\pm 1}{\sqrt{[z_{11}(1/y_{22}-z_{22})]}}\begin{pmatrix} z_{11} & -z_{11}/y_{22} \\ 1 & -z_{22} \end{pmatrix} \quad \ldots\ldots (7)$$

In view of the definitions (3) the first expression on the right-hand side of equation (7) is identical with that obtained by Mr. Hinton; the second expression is alternative.

Yours faithfully,

S. R. DEARDS,

The College of Aeronautics.

The author replies:

DEAR SIR,—I am indebted to Mr. Deards for drawing attention to the classical analysis of the problem of expressing "*A*" Matrix Elements in terms of the open- and short-circuit impedance measurements. His treatment shows, once again, the power of matrix methods in the derivation of generalities which are rather difficult or tedious to do by less refined methods.

The direct method of making fourpole transformations was not adopted in the article because it requires a greater knowledge of matrix algebra and would therefore appeal to a small minority of readers. If written at the same level, that is, from the defining equations and assuming no prior knowledge of matrix algebra, it may have proved somewhat indigestible as, not only would one have to derive the inverse matrix, but also the transformations of the "*Z*" to the "*A*," and make some explanation of the change in the sign of some matrix elements when the networks are turned end over end so that the direction of power flow is reversed.

In short, Mr. Deards' equations (1), (2) and (3) can only be written down on sight (and understood), by people already skilled in the art, but these people are not likely to require the article as they can very well do their own analysis.

A far wider reading public is well acquainted with equivalent network concepts, and this approach does, in my opinion, give some reality to what might otherwise appear to be just a clever manipulation of abstract symbols according to the rules of an equally abstract game.

These remarks are not intended to detract from Mr. Deard's excellent contribution, but to bring out the point that the topic must be worthy of the treatment otherwise an article is reduced to a tedious technical note which few people will bother to read.

The real point of both my articles on this subject, which I sincerely hope has not been missed, was to encourage the use of "*A*" matrices by showing that a great deal of useful work can be done with no more knowledge than the defining equations and the observed rule of "multiplication" corresponding to the connexion of networks in cascade.

Yours faithfully,

W. R. HINTON,

Staines, Middlesex.

BOOK REVIEWS

Photoelectric Multipliers

By S. Rodda. 180 pp., 46 figs. Demy 8vo. Macdonald & Co., Ltd. 1953. Price 22s. 6d.

THIS monograph, by an author well known for his work in the field of secondary emission and photoelectric devices, is intended to give a fairly simple account of photomultiplier tubes for users of these powerful tools who wish to obtain a more complete insight into their underlying physical principles. The emphasis is thus on basic physics, tube characteristics, and tube applications, rather than on methods of tube manufacture. The author has also brought together a great deal of information from the published literature in order to enhance the value of the book to those more skilled in the art. The pursuit of this aim has, however, led to the inclusion of a certain amount of matter of rather ephemeral interest.

Two introductory chapters summarize the relevant facts on secondary emission and photoelectricity. The latter of these includes a clear account of the definition of sensitivity in microamps per lumen, and gives a useful table showing how the sensitivity of Cs-Sb and Cs-Ag surfaces varies with the colour temperature of a tungsten illuminant.

Chapter III is an historical survey of early designs of secondary emission multipliers, and leads on to a most valuable resumé of Rajchman's 1938 thesis on electrostatic multipliers, in which the essential design features of this class of tube are clearly described.

The design and characteristics of commercially available tubes are discussed in Chapters V and VI, which cover types with focused dynode structures, such as the RCA 931 and 5819 and the range of EMI tubes with venetian blind electrodes. The reader should remember that both RCA and EMI have added new tubes to their lists since the data of these chapters were collected.

The statistical origin of noise in the output of photo-tubes and multipliers is explained in Chapter VII, and its magnitude is compared with the noise signals due to resistors and valves. The importance of high photosensitivity is stressed.

Methods of measuring small output currents from multipliers are described, and lead on to a useful discussion of applications in spectroscopy, astronomy and photometry. Chapter X is devoted to television type applications, and the opportunity is taken to discuss the advantage of secondary emission multiplication in camera tubes.

Two chapters on nuclear radiation detectors, and an appendix, close the book. Chapter XII deals with particle multipliers, of Be-Cu and similar materials, which find application in the detection of heavy ions.

Chapter XI, on scintillation counting, has obviously suffered from a delay between collection of the material and publication so that much of the information given tends to be obsolete, having been published at a time of rapid advance in the subject. In particular, the data given on the relative efficiencies of the main organic phosphors are in inverse order to those which are now accepted for these materials. It would have perhaps been more in keeping with the main part of the book if a fundamental treatment of the phosphor-photomultiplier relationship had been given, rather than a snapshot of the subject as it was in 1950 to 1951.

Apart from some indecision on indices in Chapters VII and VIII, and a persistent misspelling of scaler as scalar in Chapter XI, the production is free from misprints. Printing and binding are of good quality, and the illustrations are clear and well proportioned. At 22s. 6d., the monograph is not dear by modern standards, and may confidently be recommended as generally fulfilling the aim of the author.

J. SHARPE.

Die Gestalt Der Elektrischen Freileitung
(The Shape of the Electric Overhead Line)

By Dr. Milan Vidmar. 199 pp., 49 figs. Medium 8vo. Verlag Birkhäuser, Basel. 1952. Price S.fr.19·75.

THIS is not a book for the beginner. It is pleasant to note that its author has lost nothing of his very personal and original style which is well known also from his previous books on transformers and electrical machines. Controversial though the treatment may be in some instances there is no doubt that the designer as well as the user of overhead lines will find many thought-inspiring ideas developed in this volume. Economical aspects are given preponderance. When nearly forty years ago Vidmar's first book on transformers appeared, Korndörfer stated in his review: the book "is written by an expert who lives in and with his problems and knows how to describe them in a fascinating manner." The same may be said about the present volume.

In an introductory chapter the general problem of giving the overhead line its proper shape is discussed on the basis of Kelvin's rule requiring the balance between the amortization of prime costs and the running costs of current transmission. A refinement of this rule is proposed for the particular problem of transmission lines and special consideration is given to the problem of service interruptions. In the next chapters the choice of the most suitable span, of the cross-section of the three-phase line, of the diameter of the conductor, of the various states of the conductor and of the material used for it are discussed. A remarkable feature in this last respect is the recommendation of pure aluminium conductors not reinforced by steel wires for certain cases [see also Science Abstracts B 1439 (1953)]. This proposal certainly merits careful investigation by those concerned. In dealing with the most economical span a very simple formula is derived and its validity is confirmed by practical experiences on the transmission line from Boulder Dam to Los Angeles and on the lines of the British grid system. A final chapter deals with shaping the overhead line as regards its electromagnetical properties. An interesting result to which the author has been led by his investigations may be of some value in the future development of high power transmission. He has found that the ohmic voltage drop in a line loaded with its natural power has only half its expected value if the line shunt conductance is negligible. But, as the author admits, the practical saving due to this discovery will not be very considerable. Vector diagrams and circle diagrams for transmission lines are discussed and some examples of their application are given.

That the author is an original thinker is also shown by the fact that only very few literature references are presented. In this respect one is reminded of the books of C. P. Steinmetz although the mathematical demands on the student are less exacting. The book is very well produced.

R. NEUMANN.

Primer of Electronics and Radiant Energy

By Don Caverly. 330 pp., 44 figs. Demy 8vo. 2nd Edition. McGraw-Hill Publishing Co., Ltd. 1952. Price 47s.

THIS excellently written, printed and illustrated book is one of those rare educational volumes which are so interesting to read that the reader absorbs knowledge quite painlessly.

It covers much of the enormous field of electronics from a basic conception of atoms to such things as fluorescent lamps, radar, television, the effect on plant life of various amounts of light, cosmic radiation, nuclear fission, sound recording, diathermy and a great many others.

The treatment of each is necessarily limited, but is sufficient to give the reader some idea of the subject and is discussed in an easy and authoritative manner which is very simple to follow. It is essentially a digest. It follows no real sequence and is practically impossible to review adequately.

This reviewer found it on the whole very satisfactory and the complaints are small ones. One criticism is of the illustrations on page 239 which are intended to show the workings of a triode valve by comparing it to water in a pipe. The triode is drawn on its side and underneath is the drawing of a "T" joint in a water pipe with a valve in the centre limb. The obvious comparison is that the anode current in a triode (or the water flowing out of the right-hand top pipe) is the difference between the cathode current (or the water flowing into the top left-hand pipe) and the grid current (the valve controlled water flowing down the centre pipe).

It is also a pity that so much space should be consumed on electricity and magnetism including Ohms Law, and the effect of resistors in series and parallel.

The book, which costs 47s., contains 330 pages only, and of these approximately one-sixth is absorbed in this way. It might have been better to assume that the reader either knew as much as is covered in this chapter or could obtain knowledge and pleasure from the book without it.

On the whole a pleasant book to read to find out something of what is going on in many of the branches of electronics.

C. H. BANTHORPE.

The Resonant Cavity Magnetron

By R. S. H. Boulding. 147 pp., 80 figs. Demy 8vo. George Newnes Ltd. 1952. Price 21s.

THIS book can be recommended, almost without reservation, to both those who wish to learn and those who need to know about the mode of operation of the modern magnetron.

The single presentation in the first part of the book of the complicated phenomena occurring in a magnetron should provide no difficulties to the newcomer to the subject even though he may be of limited mathematical ability and this treatment will be found refreshing to the expert.

It is thought, however, that the short Chapter VII would have been rendered much more useful had it there been shown how simply the equation of the threshold line is related to its point of intersection with the cut-off parabola and this would have allowed fuller discussion of the possibilities of scaling magnetron designs.

The desires of the magnetron user have obviously been kept in mind as is shown by the treatment of the Rieke diagram and the long line effect but the reader will learn little of the modern techniques of actual construction. These techniques are, however, common to or developed from those used in the transmitting valve industry and it is probably unfair to expect any treatment of them in a volume of this size.

H. A. H. BOOT

Modulators and Frequency-Changers

By D. G. Tucker. 232 pp., 115 figs. Demy 8vo. Macdonald & C., Ltd. 1953. Price 28s.

THE scope of the book is clearly stated in the introduction; it concerns modulators for use in line and radio systems and is restricted to low power level amplitude modulation at frequencies up to 10Mc/s. It deals in detail with the design and performance of modulators and frequency-changers employing rectifier elements or receiver type valves, in particular with series, shunt and ring modulators. The book is the outcome of the author's many years of design and research experience, and gathers together much material otherwise available only in his papers in a variety of journals and in Post Office Research Reports of limited circulation; it should be warmly welcomed by all engineers who have to do with the design or application of modulators. The book should also appeal to communications students by virtue of the realistic approach adopted towards modulation, which is regarded as a deliberate process aimed at an optimum result rather than a phenomenon arising indirectly from the non-linear behaviour of a circuit element.

An extensive treatment of the principles of amplitude modulation and modulating circuits in the early chapters of the book provides a good background for subsequent discussion of detailed design considerations. The process of amplitude modulation is expressed in terms of the action of a modulating function, usually of approximately rectangular waveform, generated by one of the two signals involved; the detection of single and double sideband signals is treated in the same way. An important inclusion is polyphase modulation, though it is not made clear that at least a three-phase system is required to produce a phase sequence. For purposes of analysis, modulator circuits are in most cases regarded as switched linear circuits with idealized rectangular modulating functions.

Later chapters show how the characteristics of practical modulator elements depart from the ideal, causing modification of the modulating function and deterioration of modulator performance; methods of evaluating these effects are given. Methods of analysis for modulators (series, shunt and ring) with frequency dependent rectifier elements and terminations are also described. The book concludes with a discussion of the improvement of modulator performance which can be effected by the application of negative feedback, and an examination of various forms of modulator distortion.

The book is written in an attractive style and the treatment is clear throughout. No advanced mathematics is used, and it is evident that the author has taken pains to avoid unnecessary algebraic manipulation, which could easily have made the presentation of the subject tedious. The text is illustrated by a large number of diagrams and graphs, and a praiseworthy feature is the inclusion of numerical examples and experimental results for illustrative purposes. An extensive bibliography is provided.

A. R. BOOTHROYD.

Wireless and Electrical Trader Year Book 1953

264 pp. Demy 8vo. 24th Edition. Trader Publishing Co., Ltd. Price 10s. 6d.

A NEW feature in this edition is the Mains Voltage Directory which covers all the principal towns in Great Britain. The comprehensive list of the I.F. values of commercial radio receivers which have been marketed during the past five years has been revised and extended. Other time-saving data ranges from specifications of current radio receivers, legal information and a directory of trade associations. The Directory sections are printed on tinted paper for ease of reference.

One of the principal aims of this book is to assist traders to keep abreast of the constant changes in the names, addresses, telephone numbers and products of the firms engaged in the radio and electrical industries.

CHAPMAN & HALL

Ready in the Autumn

RADIO RECEIVER DESIGN

PART I

Radio Frequency Amplification and Detection

by

K. R. Sturley

PH.D., B.SC., M.I.E.E., SEN.M.I.R.E.

Second Edition Revised and Enlarged
672 pages Profusely illustrated About 45s.

RADIO ENGINEERING

(VOLUME I)

by

E. K. Sandeman

PH.D., M.I.E.E.

Second Edition Revised and Enlarged
804 pages Illustrated 60s. net

THE INSULATION OF ELECTRICAL EQUIPMENT

Edited by

Willis Jackson

D.SC., D.PHIL., M.I.E.E., F.INST.P.

384 pages 152 figures About 42s. net

37, ESSEX STREET, LONDON, W.C.2

VOLTAGE STABILIZERS

By

F. A. Benson, M.Eng., A.M.I.E.E., M.I.R.E.
(*University of Sheffield*)

Price 12/6

This monograph describes the various devices employing saturated elements, glow-discharge tube circuits and thermionic valve arrangements for voltage stabilization. A comprehensive bibliography is included.

•

CATHODE RAY TUBE TRACES

By H. Moss, Ph.D. **Price 10/6**

This monograph is based on a series of articles published in Electronic Engineering and contains in addition, the elementary theory of common types of traces with notes on their production.

Order your copy through you bookseller or direct from:—

Electronic Engineering

28 ESSEX STREET, STRAND, W.C.2

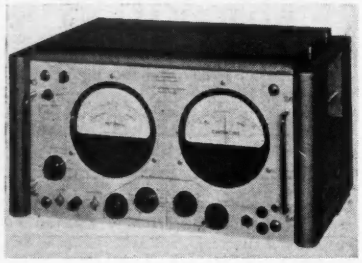
ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Phase Sensitive Voltmeter

(Illustrated below)

COVERING a frequency range of 20c/s to 20kc/s, this instrument indicates on two 6in. centre zero meters the in-phase and quadrature components of an applied test voltage with respect to a given reference voltage. Precision thermo-couple type wattmeters are used to indicate the levels. Their principle advantage lies in the fact that the indicated values of the resolved components are unaffected by the presence of harmonics or spurious frequencies in the signal under test, provided that the reference signal is of sine waveform. The provisional accuracy of indication is better than ± 2 per cent of full-scale on all ranges. The input range for both signal and reference channels is 15mV-15V in seven half decade sensitivity



ranges. Other features include an input impedance for both channels in excess of 50MΩ; provision of internal or external earthing to obviate earth loops, and an internal regulated H.T. supply.

The instrument can be used for measuring the transmission characteristics of amplifiers, networks, transformers and high speed servo systems since direct indication of the resolved components at a series of test frequencies enables their values to be plotted easily on a Nyquist diagram. The instrument is also suitable for use with A.C. strain gauge systems since by switching the quadrature meter out of circuit, the reference meter can be calibrated direct in strain and will provide indication free from errors introduced by phase-shift in the system or by the presence of harmonics.

Solartron Laboratory Instruments, Ltd., 22 High Street, Kingston, Surrey.

Plastic Film Capacitors

(Illustrated centre column)

THE "Plastapack" plastic film capacitor is a high performance component for use in instruments where capacitors of the highest possible grade are required, as for example computors and medical and industrial equipment. The dielectric consists of a specially treated form of polystyrene film and the complete capacitors are hermetically sealed.

The outstanding feature is the exceptionally high insulation resistance, this is indicated in the following comparisons:—

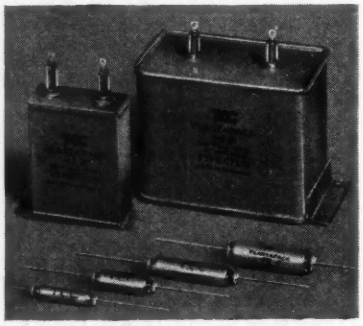
Insulation Resistance of a Typical 1μF Capacitor at 20°C

With paper dielectric	... 10 000MΩ
With mica dielectric	20 000 to 30 000MΩ
With plastic film dielectric	500 000 to at least 1 000 000MΩ

It will be readily apparent that this characteristic will be invaluable in any instrument where long time-constants are required. For normal routine testing and production purposes the manufacturers quote an insulation resistance of not less than 250 000MΩ/μF in the higher capacitance values, and in excess of 700 000MΩ absolute in all other values, at 20°C in both cases.

The decrease in insulation resistance with increase in temperature is also greatly superior to a paper dielectric. The temperature coefficient of capacitance for all types of Plastapacks is $(-150 \pm 60) \times 10^{-6}$/°C, while the power factor is of the order of ·0005 over a wide range of frequencies.

The capacitors are available in a range of values from 0·01μF to 4μF in rectangular metal cans and from 100pF to 0·005μF in tinned copper tubes. The cans have glass insulated terminals and the tubes wire terminations brought out via PTFE (polytetrafluorethylene) bungs.



The present working temperature range is −40°C to +60°C but it is hoped to raise this to +70°C in the near future. The working voltage is 350V D.C. and the test voltage 700V D.C. The standard tolerance of capacitance is ±20 per cent but they can be supplied as close as ±2 per cent or better at extra cost.

The Telegraph Condenser Co., Ltd., North Acton, London, W.3.

Instrument Soldering Iron

THE latest addition to the range of Henley soldering irons is the Solon instrument model. This is a 25W iron for use on 220-240V supply. It has an overall length of 9in., a bit diameter of 3/16in., and weighs 3½oz. This iron is completely demountable and all parts can be easily replaced.

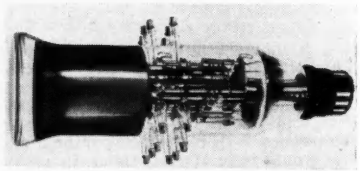
W. T. Henley's Telegraph Works Co., Ltd., 51-53, Hatton Garden, London, E.C.1.

Four Gun Cathode-Ray Tube

(Illustrated below)

THE four gun cathode-ray tubes manufactured by 20th Century Electronics Ltd. employ for independent electron guns each with characteristics similar to their type D.6. The four sets of deflector plates are brought out to side connexions arranged on either side of the bulb. The pairs of Y plates are screened both from each other and from the X plates to give freedom from intermodulation.

The four grids and four focus electrodes, together with common A_2, A_1, cathodes and heaters (in pairs) are con-



nected to the standard G.E.C. twelve side-contact cap which has four additional sockets in the base plate.

The sensitivity (V_{a2} × mm/V) of the X plates is 570 and that of the Y plates is 530; the diameter of the screen is approximately 160mm.

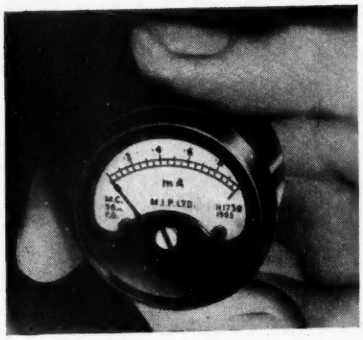
20th Century Electronics, Ltd., Dunbar Works, West Norwood, London, S.E.27.

Pullin 1½in. Meters

(Illustrated top right)

THE new Pullin Series 15—1½in. meter has been designed to satisfy the need for a precision and robust instrument wherever space and weight are limiting factors. It is an ideal meter for use in portable electronic and communications installations.

This meter is made in two types, the non-illuminated and the illuminated. The non-illuminated is available in various self-contained ranges from 50μA up to 500mA, and voltages up to 250V inclusive. The illuminated type can be supplied with self-contained ranges from 50μA up to 10mA. For higher ranges external shunts or multipliers would be required. The illuminated pattern is made possible by a simple yet ingenious method of construction. A pigmy lamp mounted on a specially designed assembly at the rear of the case is inserted within the open area of the D'Arsonval type movement. The light from the lamp passes through the translucent dial and is diffused over the scale. Lamps are



supplied for either 6·3V or 12V, and can be used on A.C. or D.C. The lamp is easily replaced without disturbing the movement or scale.

The case is of moulded bakelite and provided with back of board metal clamp for flush fitting. All meters are calibrated for non-magnetic panels. If steel panels are to be used the thickness of the panel should be stated when ordering.

Measuring Instruments (Pullin) Ltd., Winchester Street, London, W.3.

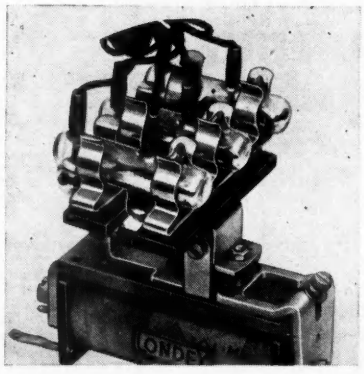
Mercury Switch Relay

(Illustrated below)

THE Londex type KR/QA is a sensitive relay fitted with heavy duty mercury switches and can be used to obviate the use of a heavy contactor in electronic control gear. The use of mercury tubes not only increases the switching capacity of the relay but also widens its scope of application, as this type of enclosed contact ensures safe operation in the presence of inflammable vapours, while control over long pilot wires and the design of intrinsically safe circuits is facilitated by the low consumption of the relay.

The relay is intended for D.C. operation and a range of windings is available up to a resistance of 20kΩ. The power required for operation varies from 0·25 to 1W depending on the number and size of mercury switches fitted. Various switch arrangements can be fitted, from three switches rated at 6A each to two switches rated at 20A each.

Londex, Ltd., 207 Anerley Road, London, S.E.20.

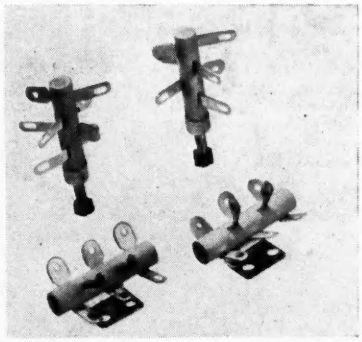


Cactus and Porcupine Tag Mountings

(Illustrated below)

THESE two components have been designed for securing and connecting components in radio and electronic equipment.

In the case of the Cactus four live tags are provided, and the component is suitable for vertical mounting, while the Porcupine has two earthing points and three live tags and is suitable for horizontal mounting.



In each case the bodies are of porcelain; all metals parts are silver plated, and a feature of both types is that the tag strips may very simply be removed and reversed, or put into any variety of combinations that is required. The Cactus is 1-1/10in. high when mounted, and the Porcupine is 8/10in. high and 1-1/10in. long when mounted.

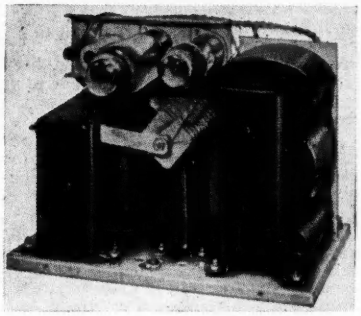
The insulation resistance is better than 100kMΩ and they are suitable for working up to 750V with a flash-over of 4·5kV R.M.S.

United Insulator Co., Ltd., Oakcroft Road, Surbiton, Surrey.

A.C. Stabilizers

(Illustrated below)

THE BAVR voltage stabilizers are made in three sizes, 200VA, 500VA,



and 1kVA, and are independent of frequency between the normal commercial limits of 47-52c/s.

The control unit is a magnetic amplifier the inductance of which varies with the D.C. passed through control coils. Stabilization is achieved by monitoring the output side and regulating automatically the D.C. component, so as to adjust the A.C. output and keep it constant within precise limits. The stability attained is 0·15 per cent for an input of 235V + 6 per cent to −12 per cent.

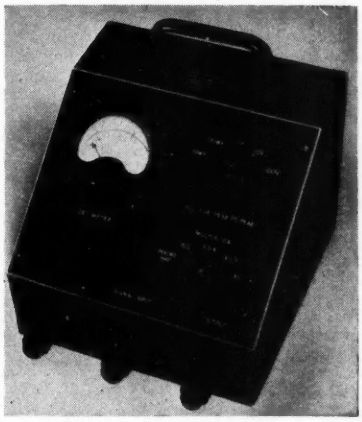
Claude Lyons, Ltd., 180-2 Tottenham Court Road, London, W.1.

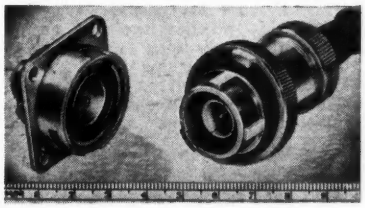
Oscilloscope Voltage Calibrator

(Illustrated below)

THE purpose of the model 207 oscilloscope voltage calibrator is to measure the input voltage to the oscilloscope by comparing the deflexion given by the signal with that obtained from a calibrated voltage source. The output from the calibrator is adjustable from 4mV to 100V (peak-to-peak) in 15 ranges and an accuracy of ±4 per cent is claimed.

Electronic Assemblies, 546 Kingsland Road, London, E.8.





Double Screened Coaxial Fittings

(Illustrated above)

THESE plugs and sockets have similar features to the Belling-Lee "Screenectors" but they are designed for double screened coaxial cable with an overall diameter from 0·156in. to 0·312in. The electrical performance is expected to be well within the requirements of specification R.I.C./322.

The outer housings are constructed of light alloy and are splash proof but not sealed. A quick action retaining ring is fitted to the plug. The dielectric between the centre conductor and the inner braid is polythene, and that between the inner and outer braids nylon filled phenolic material. To facilitate soldering the centre plug and socket contacts can be removed from the insulant.

Belling and Lee, Ltd., Cambridge Arterial Road, Enfield, Middx.

Notes from the Industry

The University of Liverpool is arranging, as part of its annual programme of advanced refresher courses for graduate research workers, engineers, and others in industry or research establishments, a course of eight lectures on the Theory and Applications of the Electric Arc. This course will describe the electrical, optical, thermal and gaseous properties of the electric arc and will then apply this experimental and theoretical data to a study of the behaviour of arcs occurring in engineering practice. The lectures will be held in the University of Liverpool on Tuesdays at 7 p.m., commencing 13 October, 1953, and the fee is £2 2s. Further particulars may be obtained from the Director of Extra-Mural Studies, 9 Abercromby Square, Liverpool, 7.

The College of Aeronautics sixth annual presentation of diplomas and prizes was held on 26 June at the College. The presentations were made by the Rt. Hon. Lord Hives. Among those who received diplomas were the following: Mr. D. J. Mayes for a thesis on "Continuous Wave Distance Measuring Equipment" and Mr. M. A. Perry for a thesis on "A New Method of Measuring Aircraft Speed and Height by Radio".

Radio Industry Training Scheme. The first certificate under the Radio Industry Council scheme for training radio technicians has been awarded to Mr. Bernard Thomas Hill who has received his practical training as an electronic engineer with A. C. Cossor, Ltd. The scheme for training radio technical and laboratory assistants was inaugurated in agreement with the Ministry of Labour and National Service to increase the number of technicians available in the industry. Trainees register with the Radio Industry Council at the age of 16 or 17 and receive a nationally recognized certificate on completion of training at the age of 21.

Metropolitan-Vickers Electrical Co., Ltd., announce that Dr. Willis Jackson has been appointed Director of Research and Education and has also joined the board of the company. Dr. Willis Jackson has been Professor of Electrical Engineering at the Imperial College of Science and Technology, University of London, since 1946.

The Chancellor of the Exchequer, Mr. R. A. Butler, has accepted the invitation of the Radio Industry Council to be guest of honour at the annual banquet at the Savoy Hotel, London, on 18 November next.

Sir George H. Nelson, chairman and managing director of the English Electric Group, recently opened the Nuclear Particle Laboratory at Queen Mary College, University of London. The inauguration of this laboratory is the first occasion on which applied nuclear physics has been officially instituted as part of the undergraduate engineer's education in this country.

The British Thomson-Houston Co., Ltd., announce that Mr. Hugh Jack has relinquished his executive duties as Chief Electrical Engineer. He will be succeeded by his chief assistant, Mr. G. S. C. Lucas.

Electrothermal Engineering Limited announce that they have now commenced production in a unit they have acquired at Hamlet Court Road, Westcliff-on-Sea, which will give the company a considerable increase of production space. The premises at 270 Neville Road, London, E.7, will still function as Head Office.

The BBC announce that Mr. F. M. Dimmock, Head of the Equipment Department, will retire from the Corporation in October this year. Mr. E. C. Drewe, Assistant Head of Research Department, will succeed Mr. Dimmock.

Oryx Electrical Laboratories have appointed as their sole distributors Messrs. A.N.T.E.X. (Anglo Netherland Technical Exchange, Ltd.) of 3 Tower Hill, London, E.C.3. All future orders and inquiries for soldering instruments will in future be dealt with by them.

New BBC Transmitting Station at Towyn. This station is now complete and will take over the service on 341m (881kc/s) from the temporary transmitter which has been operating from a caravan on the site since December, 1952. This new Welsh transmitter has a power of 5kW—the highest so far used in the group of additional low-power stations which the BBC, since 1951, has been bringing into operation in different parts of the United Kingdom to improve the reception of the Home Services.

Errata. In the description of the Mullard Electronic Temperature Controller on p. 266 of the June, 1953, issue, "±0·2°C" should read "±0·02°C".

On p. 298 of the July, 1953, issue, the reference at the foot of page 298 in connexion with "Fine Tuning Arrangements" should read "Communication from The Telefunken Co. via E.M.I. Ltd."

The following amendments should be made to Mr. C. Morton's Letter to the Editor on p. 311 of the July issue. The equation at the foot of column 1 should read $E_o/E = 1/[1 - (\alpha_1 + \alpha_2) + (1/\mu)]$. Column 2, line 11, this equation should read $m = \nu_2/(\nu_1 + \nu_2)$. The two line drawings should be transposed, i.e., Fig. C for Fig. D and vice-versa. For "Fig. 6" in the text read "Fig. C". On p. 312, column 1, for "Fig. 7" read "Fig. D".

PUBLICATIONS RECEIVED

ALL-INSULATED INDUSTRIAL WIRING SYSTEM describes the Various BICC wiring systems which are available for many domestic and industrial applications. The C.M.A. standard cables listed in this catalogue are made and tested in accordance with the Standards and Formulæ of the Cable Makers' Association and each type of cable and flexible cord mentioned has an individual reference number common to all members of the C.M.A. British Insulated Callender's Cables Limited, 21 Bloomsbury Street, London, W.C.1.

EQUIVALENT RADIO TUBES VADE-MECUM is the 10th edition in the series and is intended to be a quick reference for the possible international exchanges or substitutions of radio tubes. The tables of this book are devised to give a maximum of practical information in a simple form. P. H. Brans, Ltd., Antwerp.

ELECTRONIC THERMOSTAT, THERMOMETER BRIDGE, MULTIPOINT THERMOMETER and ELECTRONIC RESISTANCE THERMOMETERS are the titles of four brochures produced by Fielden (Electronics) Ltd. explaining the design, purpose and operation of these instruments. Fielden (Electronics) Ltd., Manchester.

PYE SCIENTIFIC INSTRUMENTS is a new catalogue featuring the scientific instruments currently produced by W. G. Pye & Co. Ltd. It includes details of a number of new instruments in addition to information on the products already manufactured by this company. Copies of the catalogue are obtainable free on application to W. G. Pye & Co. Ltd., "Granta Works", Newmarket Road, Cambridge.

BAKELITE LAMINATED GEARS is a booklet which describes the Bakelite laminated silent gear material, types of gears, machining, installation principles, lubrication, etc. There are also tables giving the physical and mechanical properties and limits of thicknesses of this material, together with illustrations. Bakelite Limited, 12-18 Grosvenor Gardens, London, S.W.1.

THE HELVIN PRESSURE BUNG is a brochure describing the Hellermann product which has provided an answer to the problem of passing electrical cables through pressure bulkheads in aircraft. Hellermann Ltd., Tinsley Lane, Crawley, Sussex.

LIST OF BROADCAST RECEIVING APPARATUS APPROVED AS SUITABLE FOR USE IN SCHOOLS is the fourth revised list issued by the School Broadcasting Council for the United Kingdom. All the apparatus mentioned has been tested by the Council under school conditions. Copies of the list and further information may be obtained from the Secretary, School Broadcasting Council for the United Kingdom, 55 Portland Place, London, W.1.

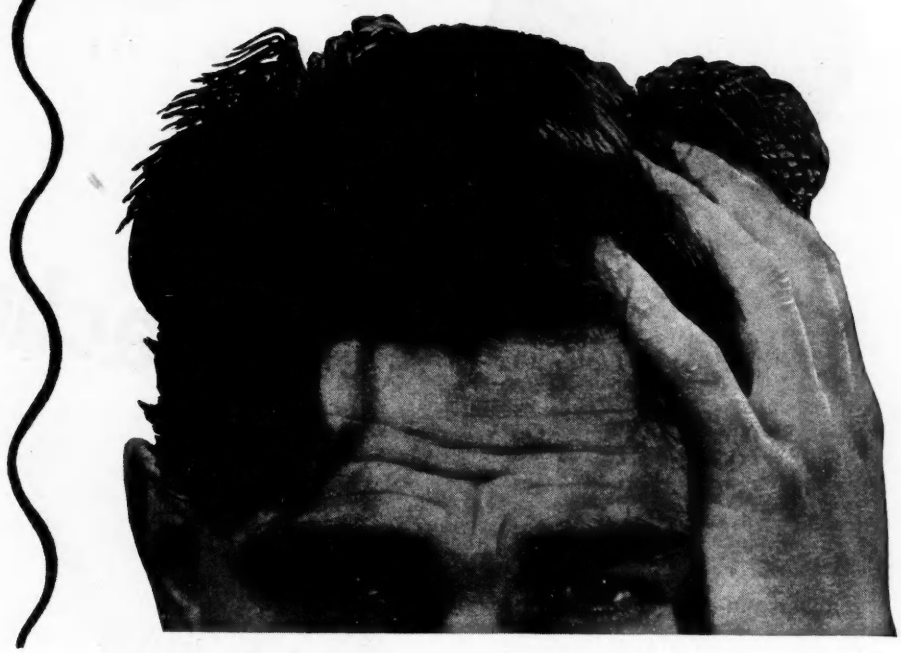
BRITISH TELECOMMUNICATIONS RESEARCH is a brochure of introduction to Taplow Court, home of British Telecommunications Research Ltd. and gives a brief insight into the work of the team of specialists working there. British Telecommunications Research Ltd., Taplow Court, Buckinghamshire.

AERIAL is a new quarterly which was published by Marconi's for the first time in January this year. It is distributed by them to some 3 000 interested people all over the globe and tells the contemporary story of the achievements of Marconi's Wireless Telegraph Company in the building and installation of every type of capital wireless equipment. Marconi's Wireless Telegraph Company Ltd., Marconi House, Chelmsford.

A CATALOGUE OF RECENT PUBLICATIONS has been issued by The Institute of Physics which covers books in the Physics in Industry Series, Journal Supplements, Monthly Journals, books on the Profession, Monographs for Students, Reports and Pamphlets, Charts and Nets for X-Ray Crystallography, etc. The Institute of Physics, 47 Belgrave Square, London, S.W.1.

TELEVISION MANUFACTURERS' RECEIVER TROUBLE CURES VOLUMES 1 AND 2 are the first two books in a series of volumes which deal with specific American television receiver troubles and their cures. These trouble cures are the American manufacturers' answers to some of the problems that may arise in their particular receivers. John F. Rider Publisher, Inc., 480 Canal Street, New York, N.Y., U.S.A.

What goes on here?



The success of an instrument, even of a whole project, frequently depends on the availability of the right material for a particular purpose. Electrodeposited rhodium is a versatile servant to instrument and electronic engineering, its unique properties often providing the solution to an otherwise insurmountable technical problem.

One of the Specialised Services of

Johnson Matthey

Data Sheet 2053, free on request, details the properties of rhodium and makes many suggestions for its application to instrument practice.

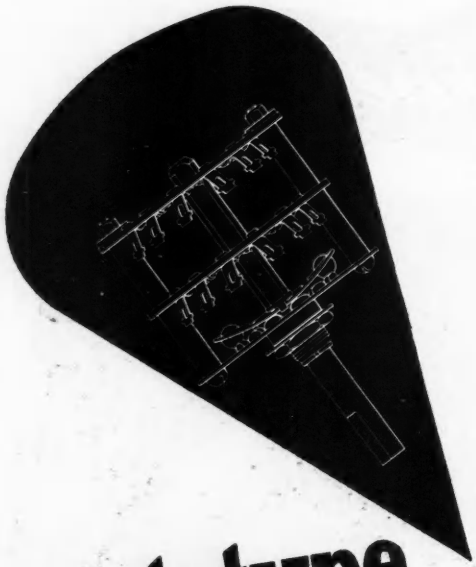
ELECTRODEPOSITED

RHODIUM

Low and stable contact resistance
Great hardness and resistance to wear
Complete resistance to corrosion
High and constant reflectivity

JOHNSON, MATTHEY & CO., LIMITED, HATTON GARDEN, LONDON, E.C.1
Telephone: HOLborn 9277 *Vittoria Street, Birmingham, 1. Tel.: Central 8004.* *75-79 Eyre Street, Sheffield 1. Tel.: 29212*

E.3



prototype headaches?

EVERYONE has his problems. Do any of yours concern prototype rotary switches? An invaluable aid to your technicians and designers, A.B. Kit Sets provide sufficient standard and interchangeable parts to build up rotary switches for experimental work and special equipment.

The A.B. Kit Set is supplied in a strong polished wooden case, and contains an ample supply of all necessary parts—**and tools.** Write now for full details and price.

...solve them with an AB kit set

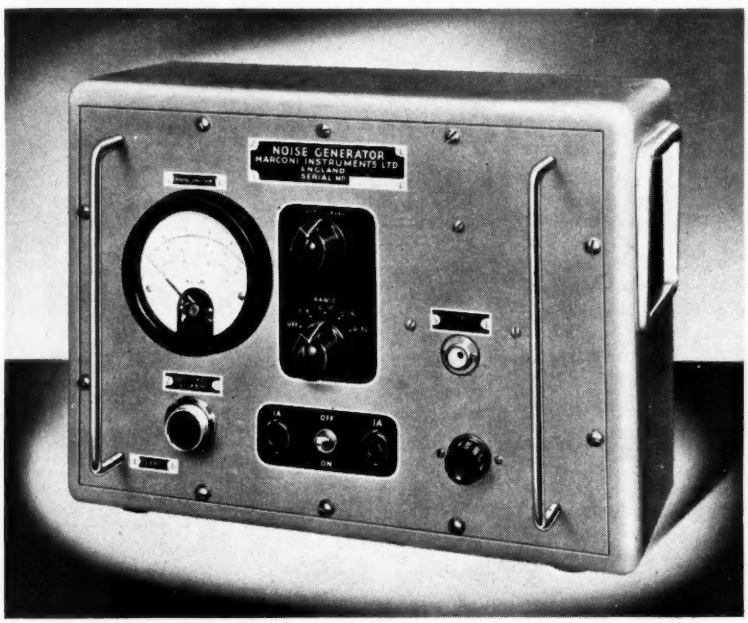
A "Return-of-Post" service is available for replacement part when needed. These can be ordered from the Parts List enclosed with every kit.

METAL PRODUCTS LTD.
16, BERKELEY STREET, LONDON, W.1
Telephone: GROsvenor 5206/7 *Telegrams:* Abmet, Piccy, London.

Figure of Merit

MARCONI NOISE GENERATOR TF 987/1

The noise factor (figure of merit) of a receiver is obtained by dividing the signal-to-noise ratio at the input by the signal-to-noise ratio at the output. Using this Marconi Noise Generator, the measurement is made by checking the output level due to internal noise, and then injecting a noise signal to double this level. The meter reading directly gives the noise factor N.



SPECIFICATION

NOISE OUTPUT CALIBRATION: *0-30 in four ranges: 0-5, 0-10, 0-15 and 0-30.*

ACCURACY: *± 0.5 db.*

FREQUENCY RANGE: *100 kc/s to 200 Mc/s.*

POWER SUPPLY: *200-250V, 45-65 c/s.*

DIMENSIONS: *11" × 15½" × 9" over projections.*

WEIGHT: *20 lbs. approx.*

MARCONI INSTRUMENTS

SIGNAL GENERATORS · BRIDGES · VALVE VOLTMETERS · WAVE METERS
FREQUENCY STANDARDS · WAVE ANALYSERS · BEAT FREQUENCY OSCILLATORS.

MARCONI INSTRUMENTS LTD., ST. ALBANS, HERTS. TELEPHONE: ST. ALBANS 6161/7

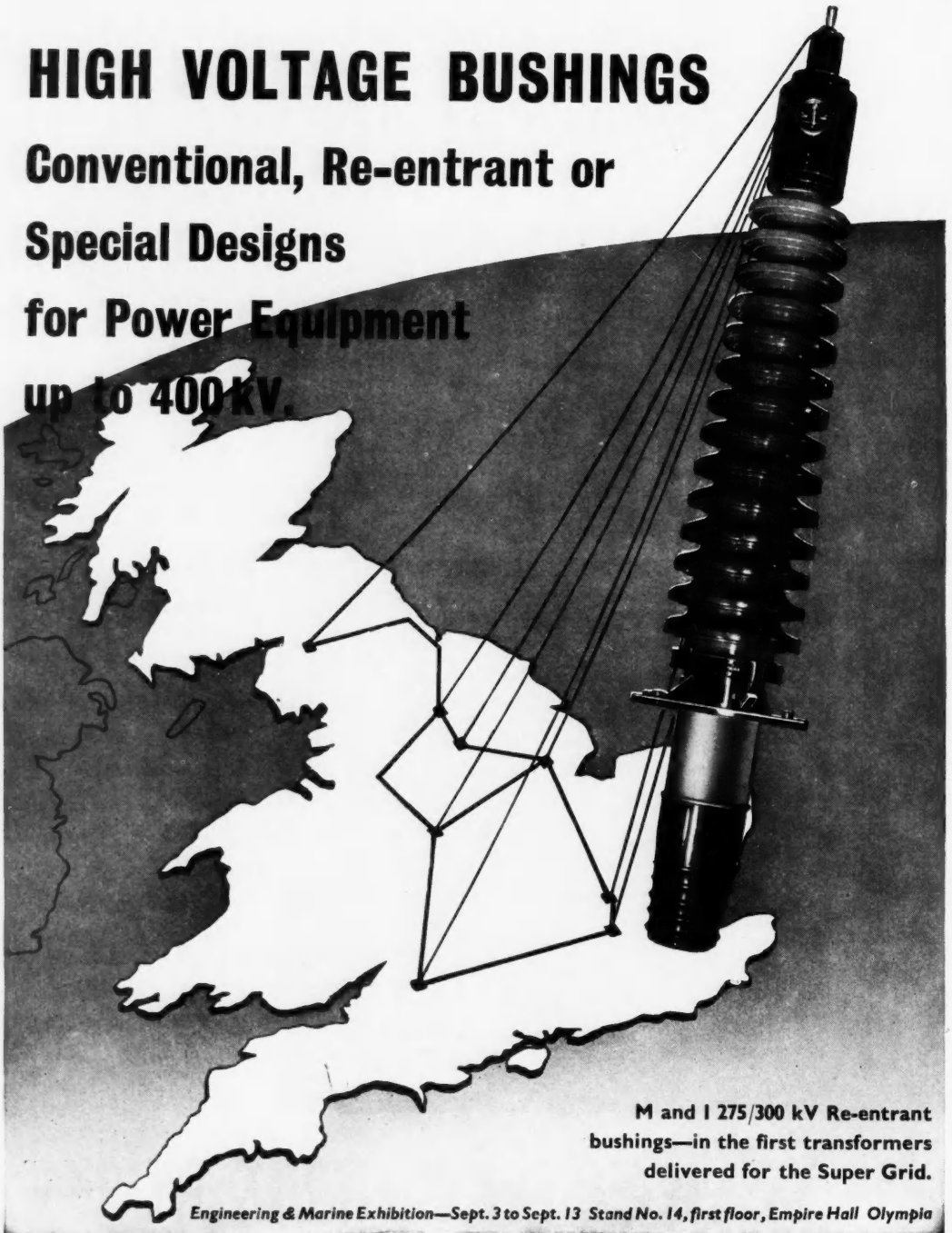
Midland Office: 19 The Parade, Leamington Spa. **Northern Office:** 30 Albion Street, Kingston-upon-Hull.

Export Office: Marconi House, Strand, London, W.C.2.

C.59

HIGH VOLTAGE BUSHINGS

Conventional, Re-entrant or Special Designs for Power Equipment up to 400 kV.



M and I 275/300 kV Re-entrant bushings—in the first transformers delivered for the Super Grid.

Engineering & Marine Exhibition—Sept. 3 to Sept. 13 Stand No. 14, first floor, Empire Hall Olympia

m and i

THE MICANITE & INSULATORS COMPANY LTD.,

EMPIRE WORKS · BLACKHORSE LANE · WALTHAMSTOW · LONDON, E.17

BRANCH OFFICES AT BIRMINGHAM, CARDIFF, GLASGOW, MANCHESTER AND NEWCASTLE-UPON-TYNE, AND REPRESENTATIVES IN MOST COUNTRIES THROUGHOUT THE WORLD.

Manufacturers of MICANITE (Built-up Mica Insulation). Fabricated and Processed Mica. PAXOLIN Laminated Materials. PANILAX Laminated Materials & Mouldings. EMPIRE Varnished Insulating Cloths & Tapes. HIGH VOLTAGE BUSHINGS & TERMINALS. Distributors of Micoflex-Duratube Sleevings, Micoflex-Durasleeve (Plastics-covered flexible metal conduit) and Kenutuf Injection Mouldings (in most thermo-plastics including P.V.C.)

X

THE RELATIVITY OF SPEED...

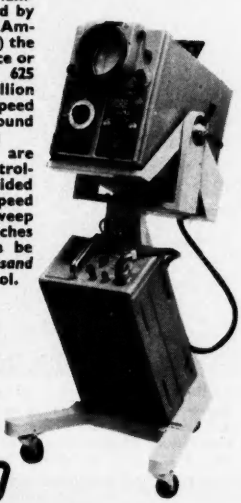
The general consciousness of the relativity of speed is not greatly affected by the amazing velocities at which human beings are now carried in British aircraft, but as everyday speeds increase, their actual values become more difficult to appreciate. In the field of electronics this feature becomes even more apparent.

The electron beam spot which produces the trace on the fluorescent screen of the cathode ray tube attains a very high speed, defined technically as the writing speed. In Nagard high-speed Oscilloscopes (Models A and L 103) the maximum Time Base writing speed for a straight horizontal trace is 55 mm per microsecond, a figure which, expressed in this form, enables the powers of the time base to resolve a clearly readable wave form to be visualized, from signals which are fast moving in time.

It may not be generally realized, however, that this speed represents 35 miles per second or 120,000 miles per hour. If ever an aircraft attained such a speed it could encircle the globe in twelve minutes.

In Nagard Oscilloscopes, the beam spot is deflected by the signal in the vertical or Y sense as well as being swept horizontally across the screen at the above speed. When a signal is applied which gives a vertical deflection of 2" at the maximum rise rate permitted by the Nagard Wide Band Amplifier (0.05 microsecond) the writing speed of the trace or spot velocity becomes 625 miles per second or 2¼ million miles per hour. (At this speed an aircraft could go round the world in 40 seconds.)

Slow speeds which are accurately linear, controllable and stable are provided by the Nagard Slow Speed Time Base. This can sweep at a uniform speed of 5 inches in 2.5 seconds and can be speeded up a *hundred thousand times* by calibrated control.



MODEL L 103 For High Speed Transients.

MODEL A 103 For Pulse Work and Repetitive Signals up to 10 Mc/s.

MODEL F 103 For General Work at Frequencies up to 1 Mc/s, High Gain D.C. Y Amplifier, Excellent Triggering.

MODEL G 103 As above but with Slow Speed Time Base.

MODEL H 103 Extra High Gain D.C. Y Amplifier up to 200 Kc/s.

NAGARD LTD

See what you measure!

18, Avenue Road, Belmont, Surrey **VIGilant 0345**

What the eye doesn't see . . .

Reproducing a strand of superfine wire measured in ten thousandths of an inch was too much for our photographer without magnification, but such limitations are not for us, and at our works wire is drawn with meticulous precision in gauges down to 0.0006.

Although the finest gauges are almost invisible, our customers know that what the eye doesn't see the heart needn't grieve over where Cromaloy V Nickel-Chrome Resistance Wire is concerned.

All our fine gauge resistance wires are now wound on light alloy spools and packed in airtight plastic containers.

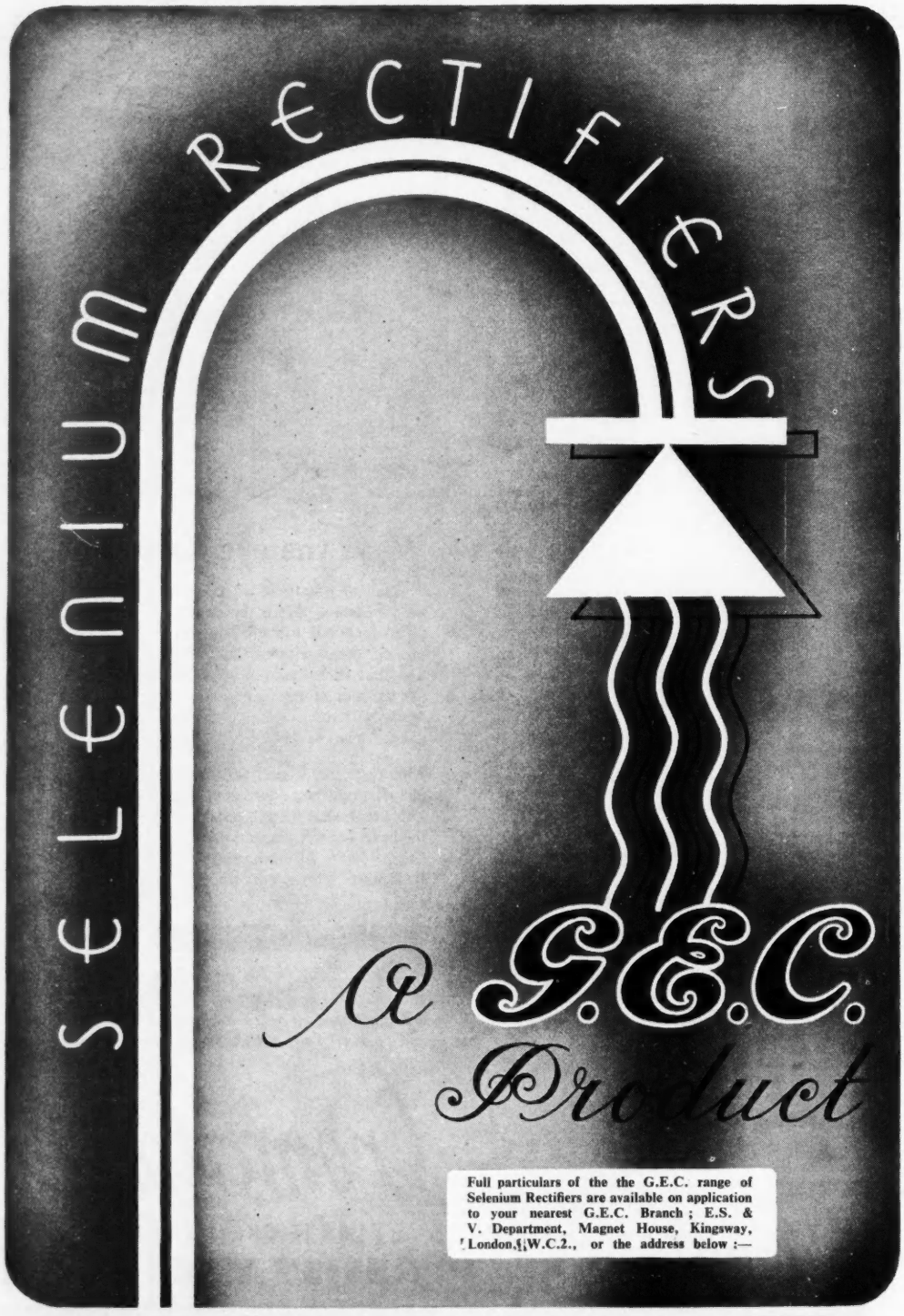
Cromaloy V

(80/20%)

NICKEL-CHROME

RESISTANCE WIRE

ASdm 19


SELENIUM RECTIFIERS
A G.E.C. Product
Full particulars of the the G.E.C. range of Selenium Rectifiers are available on application to your nearest G.E.C. Branch ; E.S. & V. Department, Magnet House, Kingsway, London, W.C.2., or the address below :—
SALFORD ELECTRICAL INSTRUMENTS LTD · SALFORD 3 · LANCS ·
A SUBSIDIARY OF THE GENERAL ELECTRIC CO. LTD OF ENGLAND

PORTABLE TEST SET

TYPE D-30-A

THIS versatile instrument is equally useful for general resistance measurements in the laboratory or for applications in the field. Completely self-contained and portable, it may be used for Wheatstone bridge measurements or for Varley and Murray Loop tests on communication circuits. Provision is also made for isolating the galvanometer, battery and balancing arm so that they may be used externally or replaced by other components.

FEATURES

Useful range of 1 to 10,000 ohms (0.01 ohms to 1 megohm with external galvanometer and/or battery).

Accuracy ±0.2% or better over most of range.

Employs standard 3V flashlamp battery.

Special galvanometer gives highest sensitivity near zero.

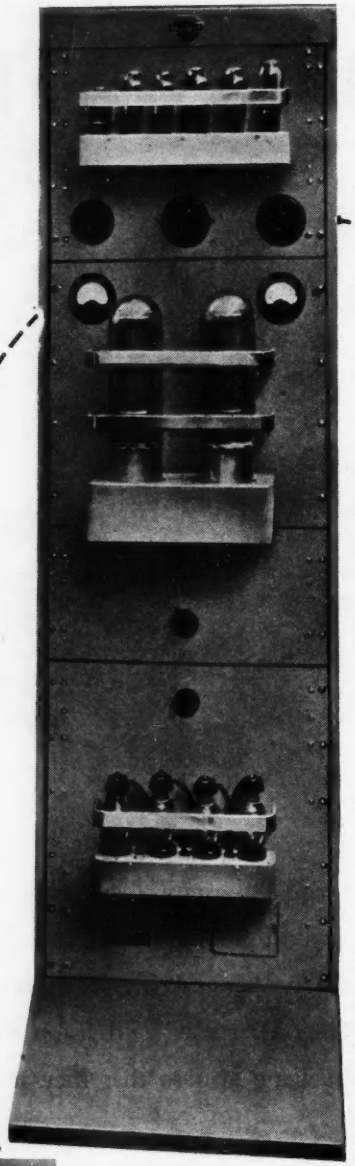
Mounted in portable hardwood carrying case.

Weight only 12 lbs.

94

MUIRHEAD & CO. LIMITED · BECKENHAM · KENT · ENGLAND

Ultrasonic Power for Industry



L.F. Ultrasonic Generator type E.7590

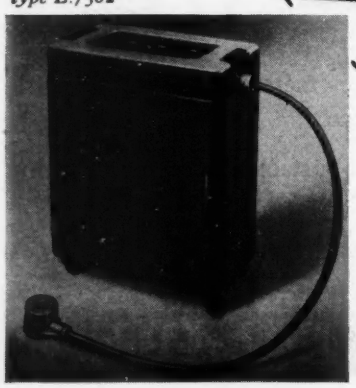
MULLARD, pioneers in the application of ultrasonic power to industry, now make available the first of a range of h.f. and l.f. ultrasonic generators that provide from 50W — 1kW ultrasonic power at frequencies in the range 15 kc/s to 2 Mc/s.

These equipments are already being successfully applied to such processes as the tinning of aluminium and its alloys, the rapid cleaning of small engineered parts that are either inaccessible or that require delicate treatment, and the dispersion of particles in liquid media.

In addition to these proved applications, high power ultrasonics offers interesting possibilities in research projects where cavitation phenomena or high particle velocities are required.

Research workers and development engineers wishing to investigate the application of ultrasonics to their own particular problems are invited to take advantage of the Mullard advisory service on ultrasonics at the address below.

H.F. Ultrasonic Generator type E.7562



Mullard Mullard

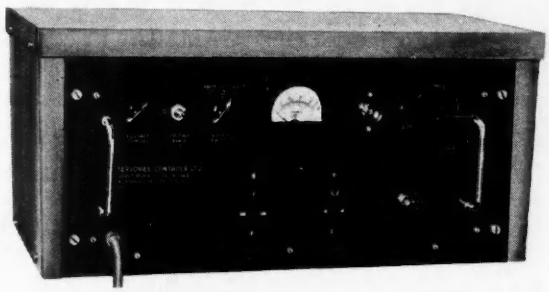
SPECIALISED ELECTRONIC EQUIPMENT

Mullard Ltd., Equipment Division, Century House, Shaftesbury Avenue, W.C.2

Electrical Control Instruments

By SERVOMEX

SERVOMEX is a registered trade mark.



A.C. VOLTAGE STABILISERS

Our standard model is the A.C.I., occupying only 8¾" in the rack and giving 0-10 amps. at 200-240 volts, completely undistorted and insensitive to changes of frequency. The speed of correction is exceptionally high.

MOTOR CONTROLLERS

These comprise a motor unit and an electronic control unit and are made for two main fields of application : Firstly, they are used in all kinds of self balancing devices where the motor is normally stationary and only operates to correct the error. The velocity feedback incorporated enables a high performance to be achieved.
Secondly, for providing a speed-stabilised motor of the very highest grade. The speed is continuously variable over a range of 1,000 to 1, and a multi range meter gives a direct reading of speed to 1 per cent of the actual speed over the whole range. The speed is constant in face of wide changes in the mains voltage, and from no load up to the full rated torque.
At present we can offer good delivery on small units suitable for laboratory instruments and small machine tools, centrifuges, sifting machines, etc.

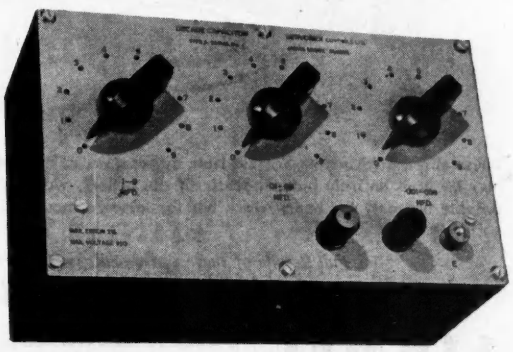
LOW VOLTAGE, HIGH CURRENT VOLTAGE STABILISERS (D.C.)

These instruments cover the range from 100 volts downwards, and one amp upwards. They use a high grade continuous servo to drive an auto-transformer, and are replacing accumulators (and auxiliary equipment) for many purposes.
Our standard model is the D.C.3., giving 1-30 volts highly smoothed D.C. at 0-7 Amps. (Both Metered) Stability is to plus or minus 25 millivolts, corresponding to less than 4 milliohms output resistance, which is achieved by purely degenerative circuits, free from any of the critical adjustments associated with certain forms of "improvement." The speed of response is such that the auto-transformer can swing from 1-30 volts in roughly one second ; small errors are corrected in a few milliseconds.

Please write for our Technical Bulletin on Low-Voltage, High Current Stabilisers.

DECADE CAPACITORS

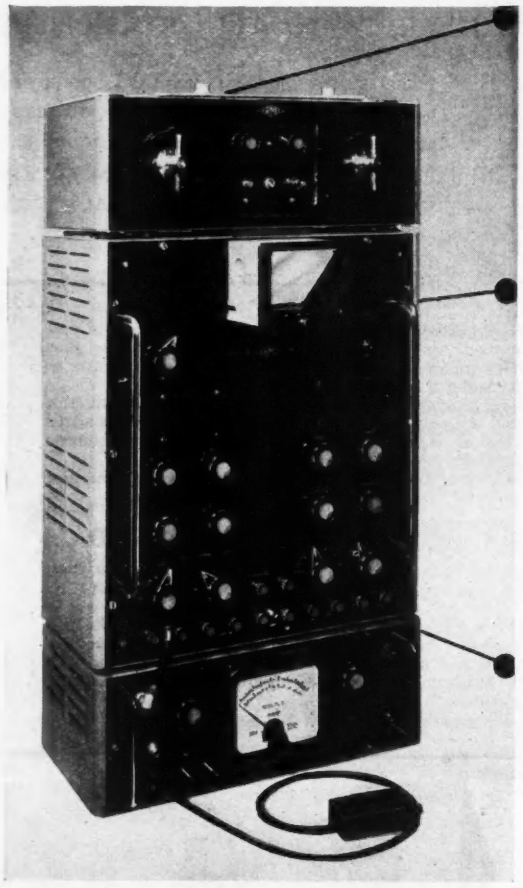
The 350 volt Decade Capacitor Type A covers the range of .001—.999 mfd., with a guaranteed accuracy of 2% (although all the components are within 1%). For the development engineer, and for uses where the highest accuracy is not required. Price £15.0.0.



DATA SHEETS FOR ALL THE ABOVE ARE AVAILABLE ON REQUEST

SERVOMEX CONTROLS LTD., *Crowborough Hill, Jarvis Brook, Sussex. Tel: Crowborough 1247*

OSCILLOSCOPE EQUIPMENT



OSCILLOSCOPE CAMERA TYPE 758

- **Mounts permanently above Oscilloscope.**
- *Photographs vertically downwards when Oscilloscope viewing slide is withdrawn.*
- **Single shot or continuous recording.**
- *Accommodates 100 feet of 35 mm. film or paper.*
- **Induction driving motor with 3-speed gearing.**
- *External footage indication and internal guillotine.*
- **F3.5 plastic lens.**

OSCILLOSCOPE TYPE 723

- **Vertical cathode ray tube with 4 in. flat screen viewed through a surface-aluminised mirror.**
- *Flat response ±2 db from D.C. to 5 Mc/s.*
- **No overloading occurs with full screen deflection over complete frequency range at 2 kV E.H.T.**
- *Variable E.H.T. voltages of 1, 2, and 4 kV.*
- **Automatic Brilliance Control Circuit.**
- *Time-base range from 0.5 seconds to 1 microsecond for full screen deflection.*
- **Versatile Auxiliary Amplifier.**
- *A deflection of 1 cm. ensures rigid synchronisation over whole frequency range.*
- **Instantaneous shifts.**

MILLIVOLTMETER AND PRE-AMPLIFIER TYPE 784

- **Overall sensitivity of 2 millivolts R.M.S. per cm. from 30 c/s to 5 Mc/s at 2 kV E.H.T.**
- *Probe Input Impedance at a frequency of 1 kc/s is 1 Megohm shunted by 14pF.*
- **Millivoltmeter frequency range from 30 c/s to 10 Mc/s.**
- *Three millivoltmeter ranges covering 0.5 millivolts to 1 volt.*

These three instruments are available as separate units, and both the Oscilloscope Type 723 and Millivoltmeter Type 784 may be used entirely independently of the others. All the units are enclosed in standard Airmec cases and are therefore suitable not only for bench work but for forward mounting on a 19 in. rack.

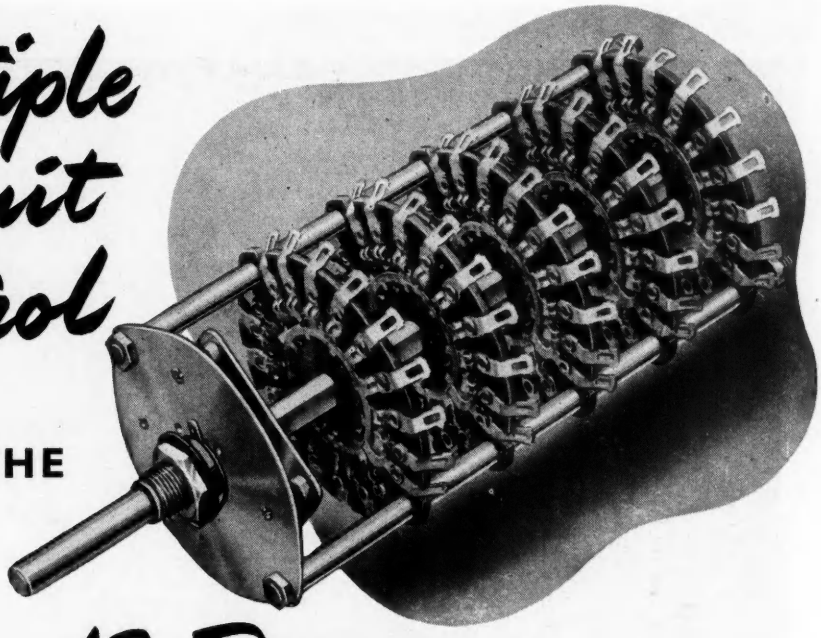
Full details of these instruments, which are available for **IMMEDIATE DELIVERY,** *will be forwarded gladly upon request.*

AIRMEC LIMITED — **HIGH WYCOMBE — BUCKINGHAMSHIRE — ENGLAND**

Telephone: High Wycombe **2060** *Cables:* Airmec High Wycombe

Multiple Circuit Control

WITH THE



New 18 Position

NSF-OAK ROTARY SWITCH

The NSF-Oak type "DL" 18-position rotary wafer switch has been developed in response to repeated demands for a high-grade component to meet the requirements of those circuit applications which necessitate increased switching facilities.

This new 18-position NSF-Oak switch embodies all the renowned characteristics of the standard NSF-Oak types, including the recently introduced "D" feature, which definitely eliminates the loosening of contacts, as a result of the application of excessive heat during soldering operations.

Positive indexing is ensured by the use of the NSF heavy-duty mechanism, and the assembly is available with or without panel and spindle seals, as desired.

The type "DL" switch is now in production, and may be specified for immediate requirements.

Switch to N.S.F. for ***better switching***

CUTLER-HAMMER APPLIANCE SWITCHES CH

OAK PRODUCTS

LEDEX

N.S.F. LIMITED

KEIGHLEY • YORKS

Phone: **Keighley 4221/5**

Grams: **ENESEF, Keighley**

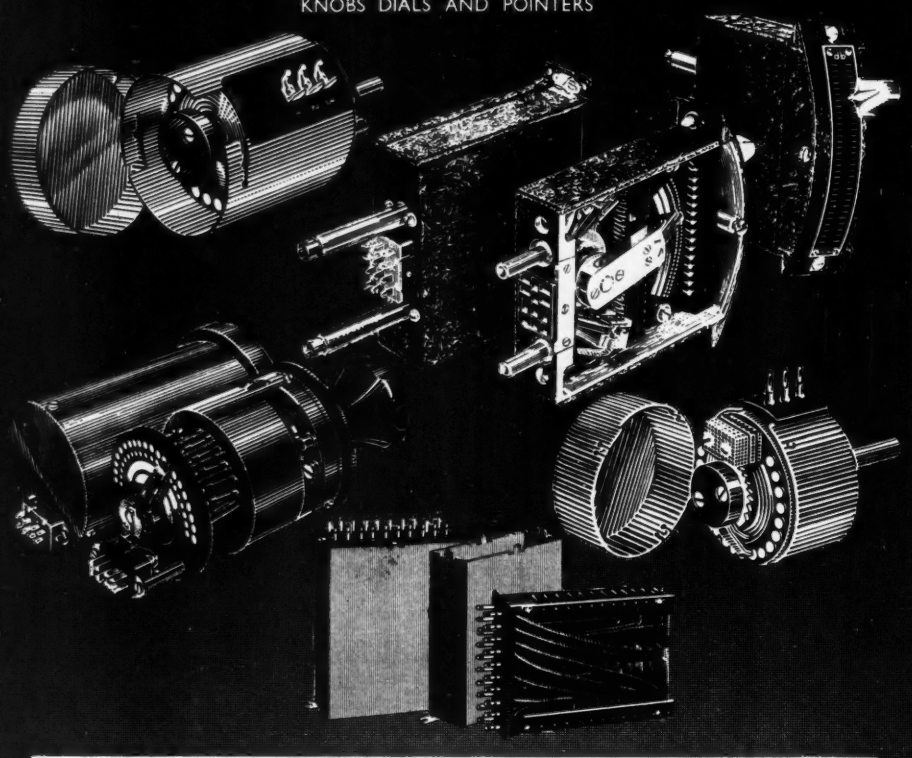
LONDON OFFICE: 9 Stratford Place, W.1. *Phone:* Mayfair 4234

Sole licensees of Oak Manufacturing Co., Chicago, and G. H. Leland Inc., Dayton, U.S.A.
Licensees of Igranic Electric Co. Ltd. for the above products of Cutler-Hammer Inc., Milwaukee, U.S.A.
The products of N.S.F. Limited are protected by patents, and patent applications, in the United Kingdom and other countries.

PAINTON

By Appointment to the Professional Engineer. . . .

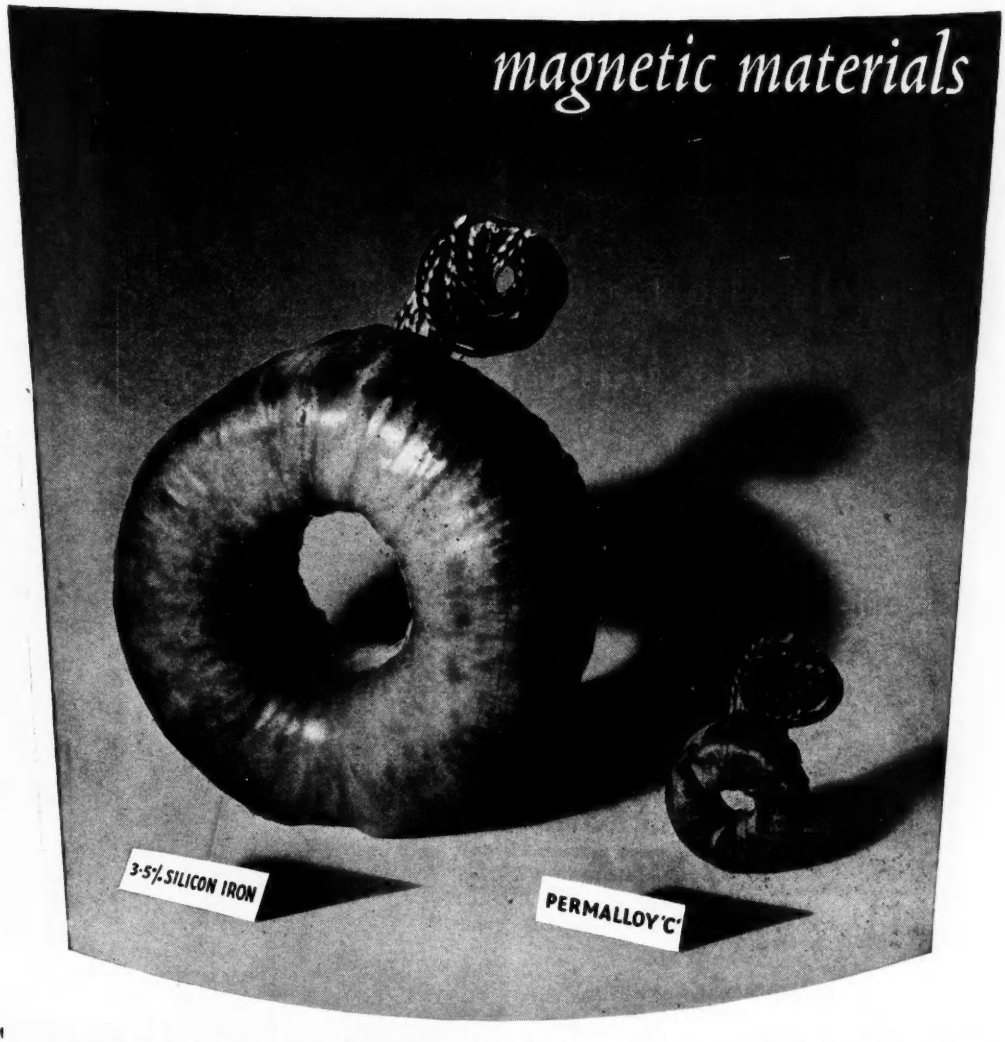
ATTENUATORS · FADERS · STUD SWITCHES AND TOGGLE SWITCHES
WIREWOUND POTENTIOMETERS · HIGH STABILITY CARBON RESISTORS
WIREWOUND RESISTORS · PLUGS AND SOCKETS · TERMINALS
KNOBS DIALS AND POINTERS



A selection of the Painton range of Attenuators and Faders.
For full details request Catalogue, Section 'A'.

PAINTON

Northampton England



Comparison of the volumes of these two coils, 264 c.c. and 6.4 c.c. respectively, will underline the advantages of *Standard* Permalloys which have played so great a part in the technique of coil miniaturization and in the conservation of raw materials . . . 40 Permalloy 'C' Coils could be used in the same space as one Silicon-Iron coil.

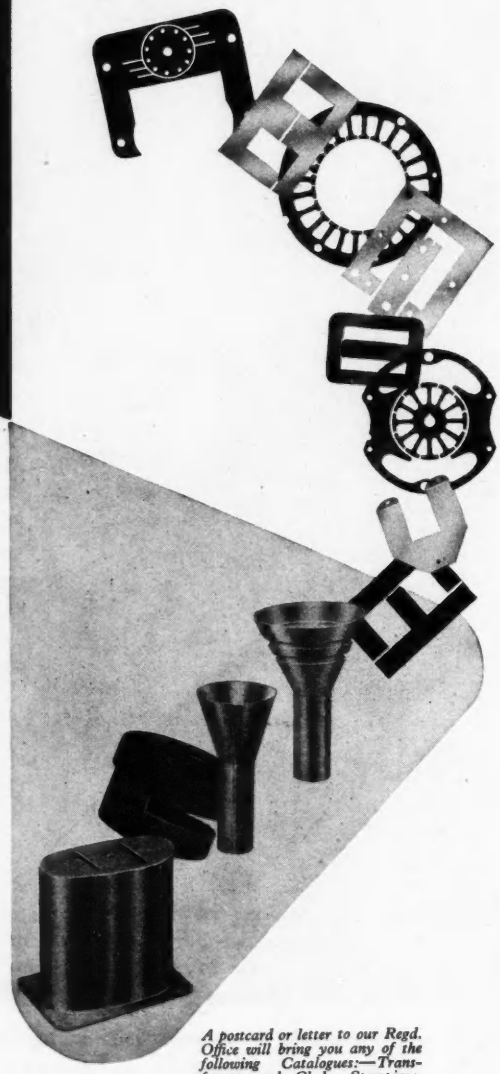
The relative characteristics of these two coils are as follows :

TEST	3.5% SILICON IRON	PERMALLOY 'C'
Nominal impedance ratio	600 : 600 ohms	600 : 600 ohms
D.C. resist. of primary winding	42 ohms	39 ohms
,, ,, ,, secondary winding	48 ohms	48 ohms
Self inductance of primary winding at 300 c/s—1 volt drop	3.0 Henries	6.5 Henries
Corresponding flux density	13.5 Gauss	336 Gauss
Leakage inductance	12.5 millihenries	0.7 millihenries
WEIGHT OF COIL	**774 GRAMMES**	**19.8 GRAMMES**

Standard Telephones and Cables Limited TELEPHONE LINE DIVISION

Registered Office : Connaught House, Aldwych, London, W.C.2 NORTH WOOLWICH, LONDON, E.16 · ALBert Dock 1401

For Quality in the Core



and efficient Screening

Electrical
STAMPINGS
and Magnetic
SCREENS
by MEA
remain unequalled

The extensive M.E.A. range of standard tooling running into hundreds of patterns paces progress in the ever expanding field of Electronics. Your requirements standard or special, in any grade of Silicon or Nickel iron Alloy will receive immediate attention.

MEA

A postcard or letter to our Regd. Office will bring you any of the following Catalogues:—Transformer and Choke Stampings. F.H.P. Motor Stampings. Magnetic Screening Tubes and Cases. Nickel Iron Alloys Data. Please address your requests to Dept. K.

For Service to Science and Industry throughout the field of Electronics

MAGNETIC & ELECTRICAL ALLOYS LIMITED

REGD. OFFICE: 101-103, BAKER STREET, LONDON, W.1. **Tel. Welbeck 3381/2**
WORKS: BURNBANK, HAMILTON, LANARKSHIRE **Tel: Hamilton 932/3/4 & 1658/9**

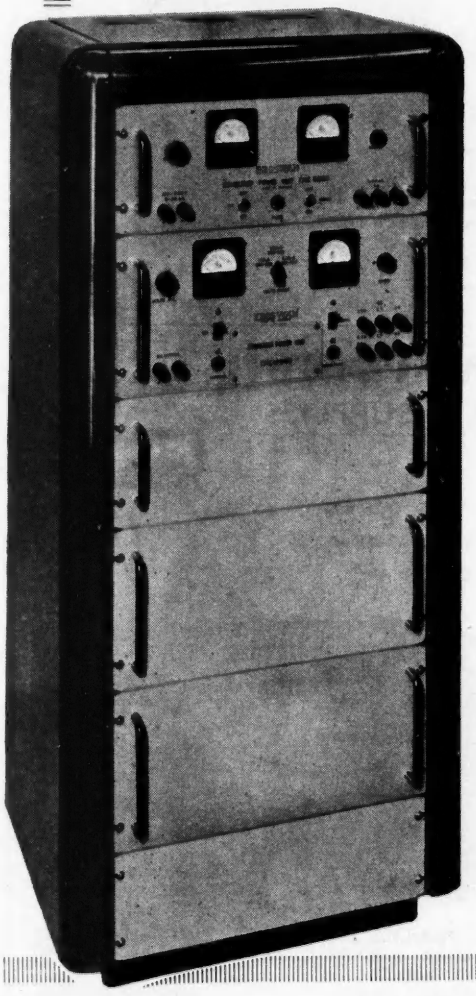
Manchester: 33 BYROM ST., DEANSGATE, MANCHESTER, 3 Tel: Blackfriars 5223.
Birmingham: 12 WESTWOOD RD., SUTTON COLDFIELD, Tel: Streetly 78586.

AF

EDISWAN

Stabilised Power Supply Units

Staffs of Electrical and Electronic Laboratories and Test Rooms frequently design and construct their own units for supplying stabilised D.C. power; but for most general needs it is cheaper and more satisfactory to purchase an Ediswan Unit. Type R.1095 covers the range 120-250 volts, and type R.1103 250-400 volts. Both units work from A.C. mains supply and are designed for standard 19″ rack mounting or for bench use. Meters are included.



PRICES

R.1095	£27 - 10 - 0
R.1103	£57 - 0 - 0

Full details on request

BRIEF SPECIFICATIONS

Type R.1095

Input.	200-250 volts, 40-100 c.p.s.
Output.	High stability, D.C. output 120-250 volts at 0-50 mA and an unstabilised 6.3v. A.C. 3 amp. heater supply.
Stability.	A 10v. change in mains input results in an output change of less than 0.15 volts. A change from zero to full load results in an output change of less than 0.15 volts.
Output Resistance.	Less than 2 ohms.
Ripple.	Approximately 2mV R.M.S.
Output Circuits.	All circuits isolated from earth. Heater supply can be operated at up to 500 volts from earth.
Mounting.	The unit is designed for standard rack mounting or for bench use. Plated bench stands are available if required.

Type R.1103

Input.	200-250 volts, 40-100 c.p.s.
Output.	High stability, D.C. output 250-400 volts, adjustable in three ranges. Maximum load is 200 mA up to 350 volts and 150 mA from 350 volts to 400 volts. In addition two unstabilised 6.3 volt A.C. heater supplies are provided.
Stability.	A 10-volt change in mains input voltage results in an output change of less than 0.15 volts. A change from zero to full loads results in an output change of less than 0.4 volts.
Output Resistance.	Less than 4 ohms.
Ripple.	Approximately 5mV R.M.S.
Output Circuits.	All circuits isolated from earth. Heater supply can be operated at up to 500 volts from earth.
Mounting.	The unit is designed for standard rack mounting, or bench use.

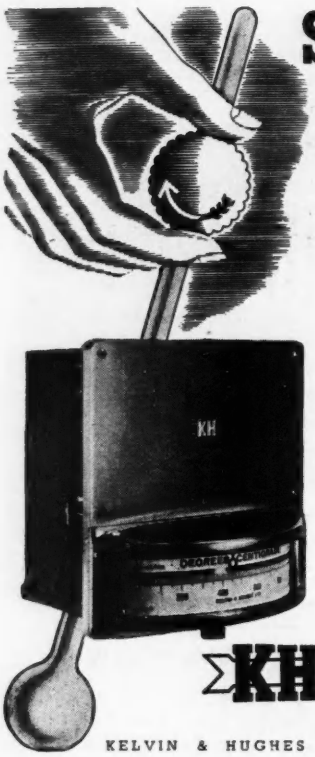
Illustration shows Ediswan Stabilised Power Supply Units type R.1095 and R.1103, rack mounted.

THE EDISON SWAN ELECTRIC CO. LTD. 155 CHARING CROSS ROAD, LONDON, W.C.2

Telephone: Gerrard 8660 · *Member of the A.E.I. Group of Companies* · Telegrams: Ediswan Westcent, London

8P114

KH26



SELECTIVE HEAT CONTROL

With the new Kelvin Hughes Electronic Controller Mk3, the smaller industrial organisation can reap the benefit of highly accurate and sensitive control without adding to normal maintenance personnel. Using a common chassis and unit construction, Kelvin Hughes have achieved standardisation on five different instruments, thus reducing servicing difficulties and cost to the user.
The range covers everything from the straightforward two-position type, to the proportional, with reset programme control. All are designed to protect the plant in the event of failure. Let us send you full particulars.

The New **KELVIN HUGHES**
Mark 3 Range
Electronic Temperature Controllers

KELVIN HUGHES
Specialists in Industrial Instruments

KELVIN & HUGHES (INDUSTRIAL) LIMITED · 2 CAXTON STREET · LONDON · S.W.1.
110 Bothwell Street, Glasgow, C.2.

ALL-POWER
REGULATED POWER SUPPLIES

MODEL 501

STABILIZED OUTPUT	200-500 VOLTS 0-250mA
UNSTABILIZED OUTPUT	470/630 VOLTS 0-250mA
UNSTABILIZED A.C.	6.3 VOLTS 10 AMPS

VOLTAGE STABILIZATION WITHIN ± 0.02%
EFFECTIVE OUTPUT RESISTANCE 0.2Ω MAX.
OUTPUT RIPPLE LESS THAN 2mV RMS.

STANDARD MODEL
19 in. RACK MOUNTING **£70**

END FRAMES
REINFORCED, POLISHED HARDWOOD
£1 - 15 - 0 per pair

STEEL INSTRUMENT CASE ... **£4 - 10 - 0**

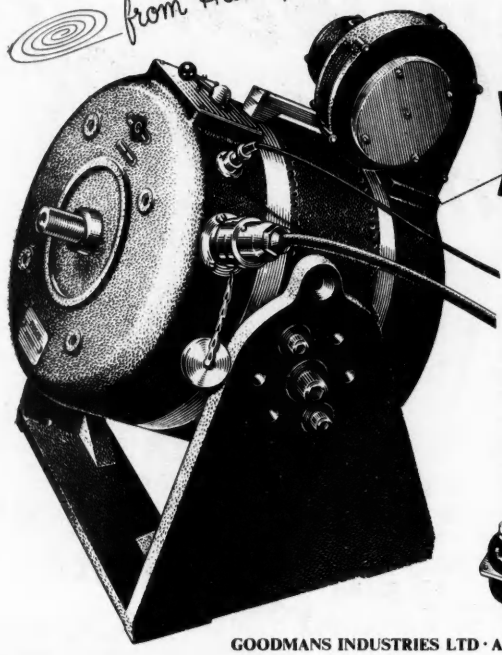
Model 501
(fitted with end frames)

ALL-POWER TRANSFORMERS LTD.
CHERTSEY ROAD · BYFLEET · SURREY
Tel: BYFLEET 3224-5

PRICES QUOTED ARE NET EX WORKS AND ARE SUBJECT TO VARIATION WITHOUT NOTICE

from Hairspring torque testing

to guided Weapon Research



GOODMANS VIBRATION GENERATORS

play their vital part

Some typical applications

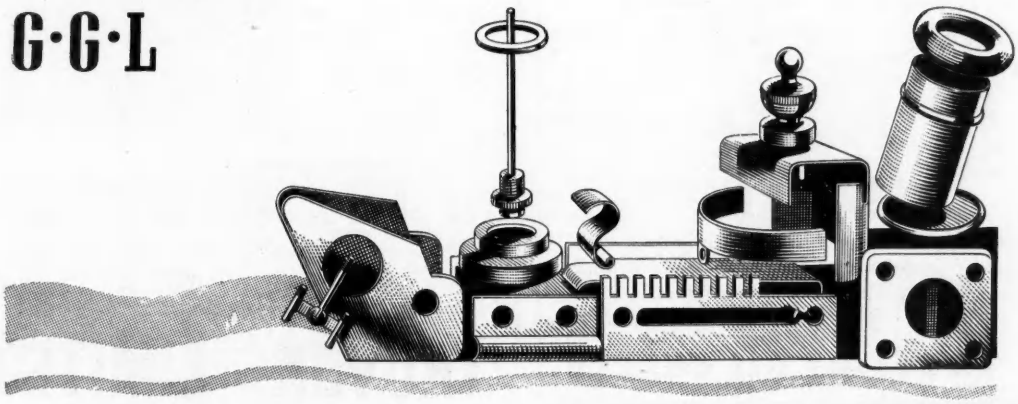
FATIGUE TESTING
ELECTRICAL COMPONENT TESTING
VALVE MICROPHONY TESTING
TORSIONAL VIBRATION TESTING
FLEXURE TESTING OF PLASTICS, ETC.
MECHANICAL STRUCTURE TESTING
SPECIALISED GUIDED WEAPON RESEARCH
or wherever ACCURATE CONTROL OF
FREQUENCY AND AMPLITUDE is demanded

Illustrated are the Model 8/600 that develops a force of ± 300 lbs and the midget Model with a force output of approximately ± 2 lbs for optical-cell research and hairspring torque testing, etc.

GOODMANS INDUSTRIES LTD · AXIOM WORKS · WEMBLEY · MIDDX · Phone : Wembley 1200 (8 lines)

It's all plain sailing at G·G·L

Modern machinery and methods keep capstan and automatic productions and sheet metal pressings flowing to you on time, at a price you will like.



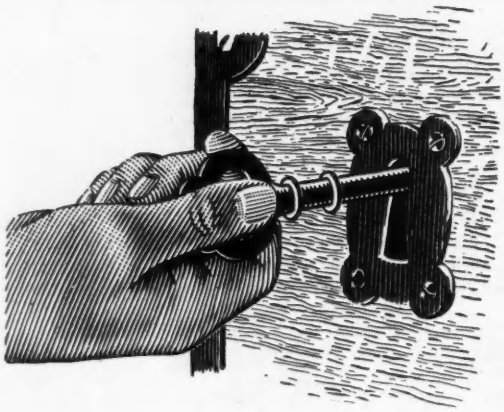
GRIFFITHS, GILBART, LLOYD & CO. LTD.

EMPIRE WORKS PARK ROAD BIRMINGHAM 18

Tel.: NORthern 6221.

G·G·L

RAGOSINE CORE LOCKING COMPOUNDS



for efficient locking

Ragosine Core Locking Compounds have been specially designed for general core locking purposes in electronic assemblies and represent a definite advance over the usual rubber string, waxes, etc. Ragosine Core Locking Compounds give the following advantages :—**1** *All grades are completely stable and will not harden, cause corrosion or support the growth of fungi in tropical climates.*

2 *They will operate efficiently throughout all climatic temperatures, acting equally as well in Arctic as in Tropical conditions.*

3 *Their use enables cores to be adjusted at any time with automatic re-locking without the necessity for further application of compound.*

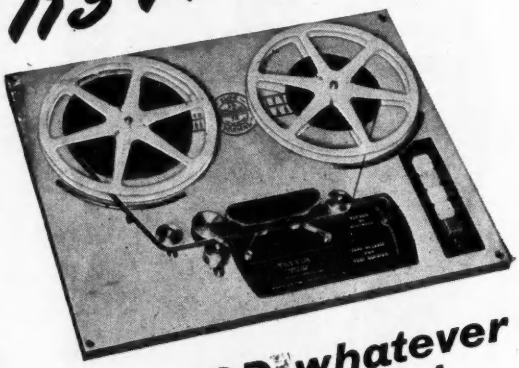
These materials have now been tested extensively under all conditions and are already in production use with many major manufacturers in this country and abroad. Write for samples and details to :

RAGOSINE OIL CO. LTD.
IBEX HOUSE, MINORIES, LONDON, E.C.3
MINERVA WORKS, WOODLESFORD, Nr. LEEDS

Ragosine Oil

ndh/21458

IT'S NEW- IT'S TRUVOX



-it's GOOD whatever you call it!

There has been difficulty in naming "OURS" —never mind the name, YOU judge the product

THESE ARE THE MAIN FEATURES:—

1. *Three-motor drive.*
2. *"Drop-in" Tape loading.*
3. *Push-button control, electrically and mechanically interlocked.*
4. *Separate push-button brake.*
5. *"Fast-forward" and "fast-rewind" without tape wear.*
6. *Silent drive eliminating "wow" and "flutter."*
7. *Half-track working, and two tape speeds of 7½ inches per second, or 3¾ inches per second.*
8. *Visual playing-time indicator.*
9. *With a suitable amplifier, the equipment covers a frequency range from 50-10,000 c.p.s. at 7½ inches per second.*

22 Gns. *MODEL TR2 200/250 volts A.C. mains only.*

TRUVOX LIMITED

WINGS DAY SEPT 19th Give for those who Gave

EXHIBITION GROUNDS, WEMBLEY, MIDDLESEX

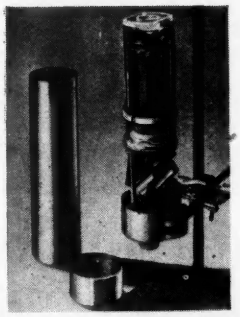
Telephone : WEMbley 1212

The Complete

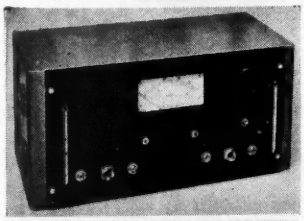
ISOTOPE RANGE

of Standard

NUCLEONIC EQUIPMENT



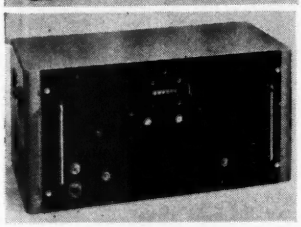
SCINTILLATION COUNTER HEAD TYPE No. 653



SCALER TYPE No. 500

PRESCALER TYPE No. 501

WIDE BAND AMPLIFIER & DISCRIMINATOR TYPE No. 652



E.H.T. SUPPLY UNIT No. 532

RATEMETER TYPE No. 550

QUENCH AMPLIFIER UNIT TYPE No. 660

All Isotope units are designed in standard rack panels and can be supplied in cabinets or with dust covers for extended rack mounting.

ISOTOPE DEVELOPMENTS LTD.

120 MOORGATE · LONDON · E.C.2

Telephone: METropolitan 9641 (5 lines)

Midland Agent: **HAWNT & CO. LTD. 59 MOOR ST., BIRMINGHAM 4**

Northern Agent: **A. M. LOCK & CO. LTD. CROMPTON ST., CHADDERTON. Oldham, Lancs**

PRECISION METAL PRESSINGS

by W·B·G

TO YOUR OWN DESIGNS

SEND FOR LEAFLET P952

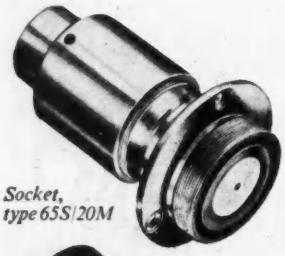
WRIGHT, BINDLEY & GELL LIMITED

PERCY ROAD. GREET

TELEPHONE VICTORIA 2295/6/7/8X

BIRMINGHAM. 11.

TELEGRAMS BINDLEY BHAM 11



Socket, type 65S/20M

Plug, type 65P/20M

Panel Mounting Socket, type 65C

TELCONNECTORS

co-axial plugs & sockets

The range of connectors illustrated enable identical 1-inch cables to be joined together, or flexible cables connected to their lead-sheathed counterparts. The flange may be fitted to either half for passing cables through panels and a panel mounting socket for terminating cable runs is also included. Telconnectors are fully waterproofed and suitable for use up to 3,000 Mc/s.

All types are readily available in various sizes and combinations. Write for publication T/1.

TELCON RF cables

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD.
Head Office: 22 OLD BROAD STREET, LONDON, E.C.2
Tel: LONdon Wall 7104
All enquiries to: TELCON WORKS, GREENWICH, S.E.10
Tel: GREenwich 3291

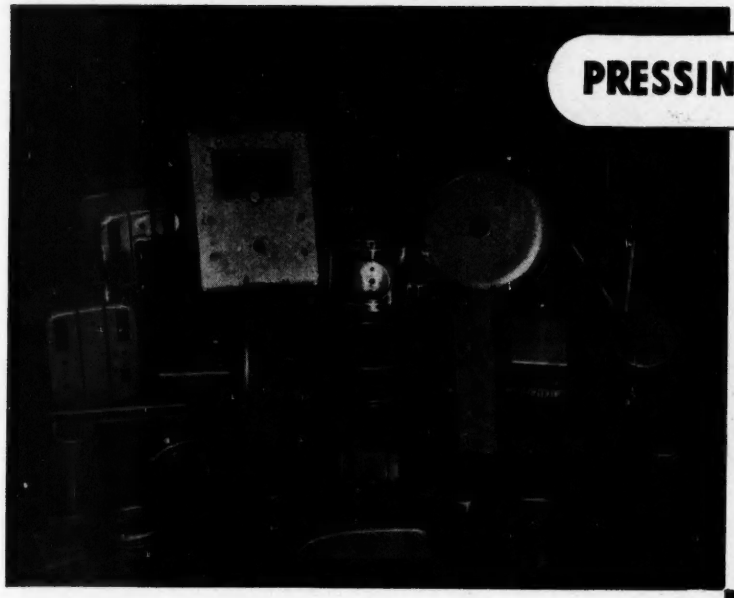
Protective Cap, type 65S

DAWE Sound Level METER

. . . for measuring the intensity of sound level over the full audible range

Technical data from: DAWE INSTRUMENTS LTD. *Instrument Division,*
130 UXBRIDGE ROAD, HANWELL, LONDON, W.7 : EALING 6215
or from your Regional Agent

Midlands	North of England	Cheshire	Scotland	West of England
Hawnt & Co., Ltd., 59, Moor Street, Birmingham, 4 *Central 6871*	A. C. Farnell, Ltd., 15, Park Place, Leeds 1 *Leeds 32958*	F. C. Robinson & Ptnrs., Ltd., 287, Deansgate, Manchester, 3 *Deansgate 6601*	Land, Speight & Co., Ltd., 73, Robertson Street, Glasgow, C.2 *Central 1082*	A. H. Radford, A.M.I.E.E., 4, Acraman's Road, Bristol, 3 *Bristol 64300*



PRESSINGS & FABRICATIONS

The items illustrated show only a few of the electrical components manufactured by us for the electrical trade in our self-contained factory. We manufacture our own Press Tools; Fabrications, Spinnings, Assemblies, and are able to undertake all kinds of metal finishes.

IMPELLERS · LAMINATIONS · METER COVERS

ADAMS BROS. & BURNLEY LTD.

Elmgrove Road · Harrow · Middlesex

Telephone : Harrow 6411 (5 lines)

INSTRUMENT PANELS MOTOR HOUSINGS MICROPHONE COMPONENTS

Economically produced with Multi-tool set up

You may not keep Boffins in your files against a sudden need for extra technical assistance, but you have them handy, all the same. A letter, or even a 'phone call, will summon them at once.

Nash and Thompson have, for more than ten years, been rendering a service to manufacturers who occasionally need technological help. Because Nash and Thompson have been consulted by so many manufacturers they have a wide experience of the unusual problem. The staff is fully qualified in chemistry, physics, electronics and production engineering, and their service covers :— **Designing and making instruments for special purposes, Consultancy on scientific problems, Fundamental research, Making-up of prototypes and mock-ups, Precision manufacture of small components, Routine analysis of materials.**

Nash and Thompson

Limited

Oakcroft Road, Tolworth, Surrey. ELMbridge 5252

The service is fully described in a booklet which also catalogues a standard range of instruments. A copy will be sent on request.

why call me a **STIFF** *nut*

A Stiff Nut is a one-piece nut which complies with R.A.E. Specification No. A.D.114—a nut provided with means of increasing the friction between the thread of the nut and that of a standard bolt to an extent that the nut may be considered self-retaining. A Stiff Nut should be as light as is consistent with strength and be able to withstand all conditions of service use. It should be of a design which does not cause undue damage or excessive wear to the thread of the bolt on which it is mounted.

A perfect description, in fact, of the G.K.N. 'Aerotight' Nut—often casually referred to as a Lock Nut or Self-Locking Nut—which has the added advantages that it can be used over and over again without loss of efficiency. Its retentive properties are unaffected by oil, water or humidity.

GKN 'AEROTIGHT' STIFF NUT

Supplied in Steel, Stainless Steel, Light Alloy, Brass and Bronze in Whitworth, B.A. and B.S.F. Threads. Recommended for all applications where vibration is encountered. Economical in use. No need for drilled holes, cotter pins, lock washers, etc.

GUEST KEEN & NETTLEFOLDS (MIDLANDS) LIMITED.
Screw Division: Box 24, Heath Street, Birmingham, 18.

S/A/2002

BALDWIN

DUNLOP

STATIGUN

FOR THE MEASUREMENT OF ELECTROSTATIC CHARGES

A self-contained battery operated instrument for the direct indication of voltage gradient: reads on three ranges with full scale values of 2 kilovolts per foot to 200 kilovolts per foot.

In use it is pointed at the charged surface and if necessary adjusted for range.

It will indicate if the charge is positive or negative.

OF PARTICULAR APPLICATION TO ALL PROCESSES IN WHICH ELECTROSTATIC CHARGES ARE DEVELOPED AND MAY BE A NUISANCE OR SOURCE OF DANGER.

It will also measure charge and resistance to earth with extra accessories.

Weight 3½ lb.
Write for Leaflet E.E. 123

BALDWIN INSTRUMENT CO. LTD., DARTFORD, KENT

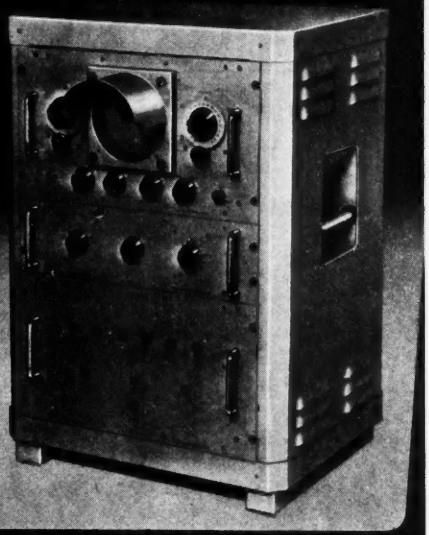
Telephone: Dartford 2989 & 2980

XU

A New Instrument for Electrochemical Analysis

CATHODE RAY POLAROGRAPH

(as developed at the Chemical Inspectorate (Woolwich) M.O.S.)



RAPID Readings can be taken in a few seconds

SENSITIVE 100 times as sensitive as a conventional Polarograph

EASY TO USE By semi-skilled personnel

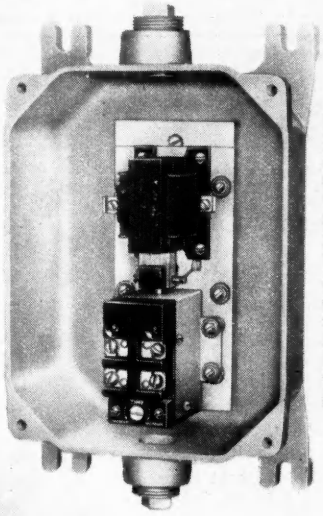
VERSATILE Equally adaptable to routine analysis or specialized research

SOUTHERN INSTRUMENTS LIMITED

(Special Products Division)

HAWLEY • CAMBERLEY • SURREY

Telephone : Camberley 1833-4 Telegraphic Address : "Minrak, Camberley, England"



This single-pole change-over switch, in which 'make' or 'break' timing can be set to operate over a range of 1/6th to 180 seconds. comprises a compact pneumatic system and a robust solenoid mounted in a fully-tropicalised case of cast-aluminium.

It is used for controlling accelerating-contactors of motor-starters; timing the opening and closing of valves in refrigeration plant; controlling sequential process operations; and for the delayed-starting of loop-circuit electrical equipment.

ELECTRO METHODS LTD OF STEVENAGE

– the first name for

PNEUMATIC TIME-DELAY RELAYS

Comprehensive technical data gladly forwarded on request.

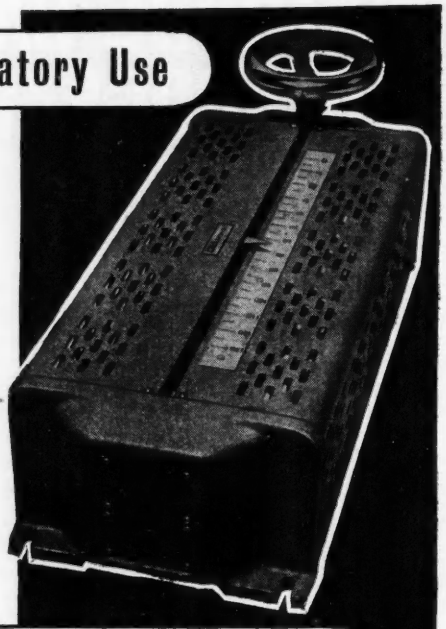
Now available for PROMPT DELIVERY

ELECTRO METHODS LTD. (Divisions PR1). CAXTON WAY, STEVENAGE, HERTS
PHONE: STEVENAGE 780

For Industrial and Laboratory Use

All types of A.C. apparatus—motors, furnaces, rectifiers, transformers—can be controlled by a single Regavolt whose output can be set, regardless of the load current, precisely at any voltage from 0 to 30% above the supply. Its rugged design for heavy industrial duty ensures reliability under severe working conditions.
Special designs can be made for incorporation in your own apparatus in addition to the wide range of single, 3 phase, hand and motor driven models listed in our catalogue No. 3131.

HIGH EFFICIENCY—
COMPETITIVE PRICE

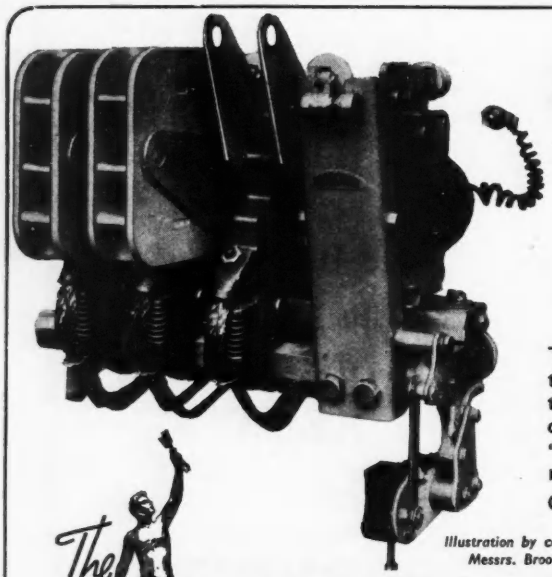


BERCO

"REGAVOLT"
REGULATING TRANSFORMER

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Specialists in the control of current and voltage for more than 25 years
Queensway, Ponders End, Middlesex. Telephone : HOWard 1492. Telegrams : Vitrohm, Enfield.

BR3131/T



When Designing

SWITCHGEAR

Two essentials are looked for in the contacts to be used. Firstly, the material specification, and secondly, the precise workmanship of the contact unit itself. "Thessco" and "Thessconite" contacts meet all requirements in the electrical field.

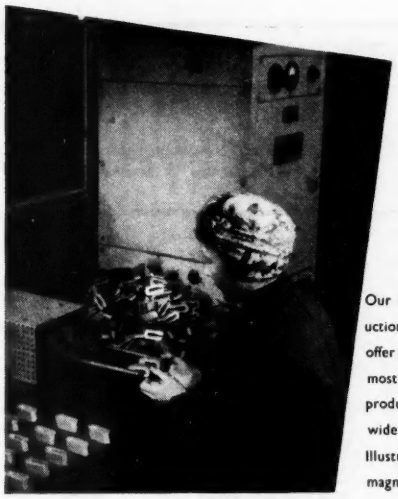
Contacts literature supplied on request.

Illustration by courtesy of Messrs. Brookhirst Switchgear Ltd.

The SHEFFIELD SMELTING Company Limited

BIRMINGHAM · SHEFFIELD · LONDON

ST. PAUL'S SQUARE, BIRMINGHAM, 3. ROYDS MILL STREET, SHEFFIELD, 4. 1, BERRY ST., CLERKENWELL, LONDON, E.C.1.



THE DARWINS GROUP

SHEFFIELD · ENGLAND

Our long association with the use and production of permanent magnets enables us to offer not only an advisory service of the most complete character, but the benefits of production technique and facilities based on wide knowledge and intensive research. Illustration shows the latest ignition half cycle magnetising equipment being used.

Craftsmen in Steel

DARWINS LTD.
TOOL STEELS · HACKSAW BLADES · PERMANENT MAGNETS · HEAT & ACID RESISTING CASTINGS

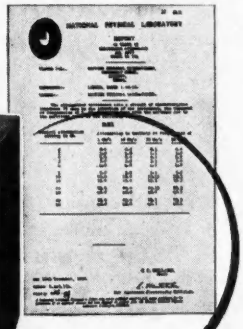
ANDREWS TOLEDO LTD.
CARBON & ALLOY CONSTRUCTIONAL STEELS

WARDSEND STEEL CO. LTD.
AGRICULTURAL & TOOL STEEL SHEETS

ANDREWS TOLEDO (WIRE ROD) LTD.
SPECIAL CARBON & ALLOY WIRE ROD

D.52

INCREMENTAL ACCURACY *Within 1% up to 70 Mc/s*
BACKED BY N.P.L. CERTIFICATE



(EXTRACT)

Table

Nominal attenuation setting in db.	Attenuation in decibels at frequencies of 1 Mc/s	10 Mc/s	30 Mc/s	50 Mc/s
0	0.0	0.0	0.1	0.2
1	1.0	1.0	1.1	1.2
2	2.0	2.0	2.1	2.2
3	3.0	3.0	2.1	3.2
4	4.0	4.0	4.1	4.2
5	5.0	5.0	5.1	5.2
10	10.0	10.0	10.15	10.3
15	15.0	15.0	15.2	15.3
20	20.0	20.0	20.15	20.3
40	40.0	40.0	40.2	40.3
20	20.0	20.0	20.1	20.3
40	40.0	40.0	40.3	40.4

MODEL RA104
WIDE FREQUENCY RANGE ATTENUATOR

It is the only unit of its type, independent of frequencies up to 70 Mc/s designed to operate between 75 ohms resistive loads.

THE ONLY COMMERCIALLY AVAILABLE INSTRUMENT

over the range 1-104 db in steps of 1 db. A National Physical Laboratory Certificate quotes the adjoining figures.

Please write for full details.

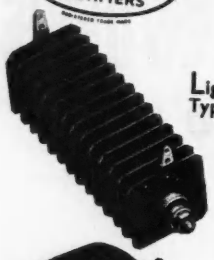
BRITISH PHYSICAL LABORATORIES LTD

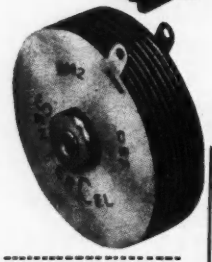
Tel: Radlett 5674-5-6 *Radlett* HERTS

*dm*BP11

SELENIUM
SenTerCel
RECTIFIERS

miniature **RECTIFIERS** for domestic **radio & television**





Light . . . compact . . . low in cost, SenTerCel Type RM selenium rectifiers offer important advantages. For example, features such as these are of the greatest interest to set manufacturers :

UNLIMITED INSTANTANEOUS OVERLOAD. There need be no limit to the size of reservoir capacitors. SenTerCel rectifiers are able to withstand the charging current of de-formed electrolytic capacitors.

LOW HEAT DISSIPATION. SenTerCel selenium rectifiers dissipate far less heat than their equivalent thermionic types.

SIMPLE ASSEMBLY. Absence of a valve holder reduces wiring. Assembly involves as little as one-hole fixing.

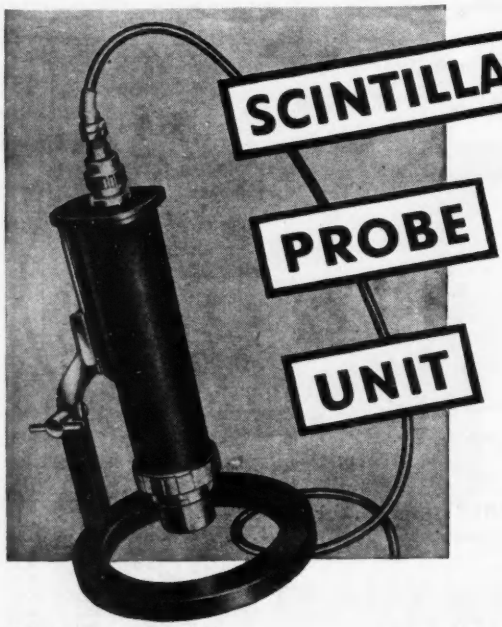
SenTerCel Type RM selenium rectifier **RATINGS.**

TYPE	RM0	RM1	RM2	RM3	RM4
Maximum ambient temperature	35°C 55°C	35°C 55°C	35°C 55°C	35°C 55°C	35°C 40°C 55°C
Maximum output current (mean)	30mA 15mA	60mA 30mA	100mA 60mA	120mA 90mA	275mA 250mA 125mA
Maximum input voltage (r.m.s.)	125V	125V	125V	125V	250V
Maximum peak inverse voltage	350V	350V	350V	350V	700V
Max. instantaneous peak current	Unlimited	Unlimited	Unlimited	Unlimited	Unlimited
Weight	0.82 oz.	1 oz.	1.4 oz.	2 oz.	4.5 oz.

SAVES WEIGHT
SAVES SPACE
SAVES COST

Standard Telephones and Cables Limited

Registered Office Connaught House, Aldwych, W.C.2.
RECTIFIER DIVISION : Warwick Road, Boreham Wood, Herts.
Elstree 2401 Telegrams : SenTerCel, Borehamwood



SCINTILLATION PROBE UNIT

NEW LABORATORY INSTRUMENT

A general purpose laboratory instrument for the accurate measurement of alpha, beta and gamma radiation. An eleven-stage photo-multiplier tube is used and a Sodium Iodide crystal of diameter $1\frac{1}{2}''$ (3.8 cm) and length $1\frac{1}{8}''$ (2.86 cm) is provided for gamma measurement.

Alternative holders for alpha and beta assay work can also be supplied.

The heavy adjustable stand enables the probe unit to be used in any position.

α β γ

Other Instruments available
Portable Beta Gamma Radiation Monitors
Portable Neutron Monitors
Rate Meters
Pulse Amplifiers

by **BURNDEPT** of **ENGLAND**

Nucleonics Division
BURNDEPT LIMITED ERITH · KENT · ENGLAND

PRESSURE TRANSDUCER

TYPE 548

J. LANGHAM THOMPSON PRODUCT

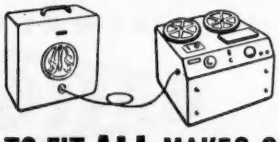
This transducer is intended for the remote indication and measurement of static pressures in the range of 0 – 25 to 0 – 4000 lbs/in².

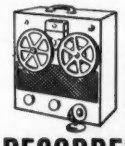
It consists of a Bourdon Tube operating a miniature potentiometer through a linkage mechanism.

Please write for full details.

J. LANGHAM THOMPSON LTD
Springland Laboratories
BUSHEY HEATH HERTFORDSHIRE

Phone: BUSHEY HEATH 2411





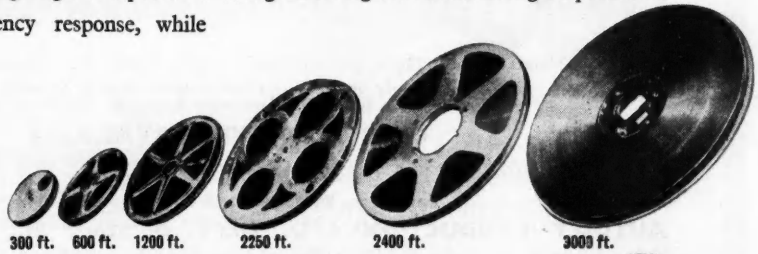
TO FIT ALL MAKES OF TAPE RECORDER

This plastic backed, strong and reliable tape offers high fidelity reproduction over a wide range of playing speeds and recording conditions.

Medium coercivity gives a high signal output with an extended high frequency response, while retaining ease of erasure. Signal/noise ratio is high; transfer and distortion negligible.

'Scotch Boy' is used by the B.C.C. and most other big recording and broadcasting corporations.

'Scotch Boy' is now available in 6 reel sizes



Write for further particulars:
MINNESOTA MINING & MANUFACTURING CO. LTD, 167 STRAND, LONDON W.C.2 TEMple Bar 6363 ANOTHER 3M PRODUCT

MILTOID LTD

STOCKISTS OF

BX
POLYSTYRENE

A first-class rigid insulating material, supplied in sheets and rods in a range of thicknesses and diameters ex stock.

•

Information and guidance on manipulation, machining and cementing available on request.

MILTOID LTD.

34/36 Royal College Street, London, N.W.1.

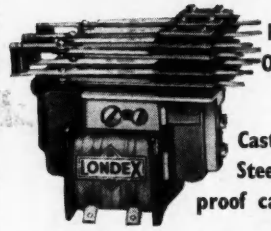
'Phone : EUSton 6467. 'Grams : Celudol, Norwest, London

ELECTRICAL AUTOMATIC CONTROL APPARATUS

Including

LONDEX TRADE MARK

RELAYS



FOR A.C. & D.C. OPERATION

Cast Iron, Sheet Steel and FLAME-proof cases available

TYPE LF Industrial Type, up to twelve contact sets. Contacts : Solid Silver, Tungsten, etc.

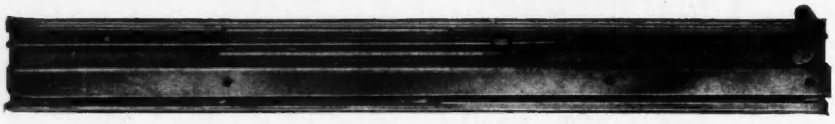
★ Write for list 77EE

LONDEX LTD. ANERLEY WORKS
LONDON, S.E.20. TEL: ★ SYD 6258

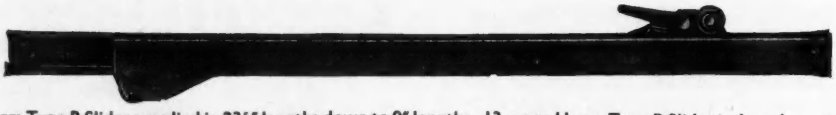
ALWAYS "FIT"

AUTOSET

SUSPENSION DRAWER SLIDES, SUN and PLANET FRICTION ELIMINATORS and SHEAVES.



Type A Slides as above supplied in 15⅝", 17⅝", 21", 23⅝", 25½" and 27½" lengths. Heavy type A Slides supplied in lengths 23⅝", 28½", 32" and 37". Type A series case strips may be drilled and countersunk or provided with ears or lugs.



Two arm Type B Slides supplied in 23⅝" lengths down to 9" lengths. 13 gauge Heavy Type B Slides in lengths up to 30".

We also supply heavy duty castors up to 30 tons capacity each, including twin pneumatic wheeled types up to 44" diameter.

OVER 7,000 TYPES AVAILABLE

Ask for Brochure.

Engineers, Patentees and Sole Manufacturers

AUTOSET (PRODUCTION) LTD., DEPT. O, Stour St., Birmingham, 18.

Phone : EDG 1143/4. *Est.* over 30 years.

Please mention " Electronic Engineering." AT 3

Locating Vacuum Leaks . . .

Quickly . .

Economically . .

EDWARDS PALLADIUM-BARRIER LEAK DETECTOR

EDWARDS Palladium-Barrier Leak Detector locates leaks of the order of 10^{-4} lusecs–a response comparable with the mass-spectrometer. Having a sensitivity sufficient for the highest standards of vacuum tightness it combines this with compact simplicity and maximum sensitivity.

Best results are obtained from the Palladium Leak Detector when used in conjunction with a pumping system specially designed for leak testing. Standard leak test pumping units are manufactured by EDWARDS — SEND FOR DETAILS.

for better vacuum service... **W. EDWARDS** & CO., (LONDON) LTD.
LOWER SYDENHAM. LONDON. S.E.26.

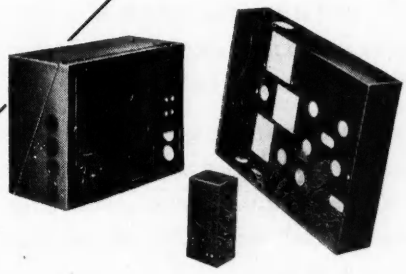
TELEPHONE: SYDENHAM 7026 (8 LINES) TELEGRAMS: EDCOHIVAC, SOUPHONE, LONDON

We are the right people to know for **METAL FABRICATION**

Whatever your particular requirements in Metal Fabricated Units or Specialised Precision work, we of Spencers are the right people to know. Our long association with the Electronics Industry enables us to handle the most intricate problems with exceptional speed and efficiency.

Our manufactures include — Cabinets, Control Panels, Transformer Tanks, Chassis Assemblies, Components, Pressings and Stampings to individual specification.

We shall be pleased to supply further details on request. Why not investigate our resources, you won't be disappointed.

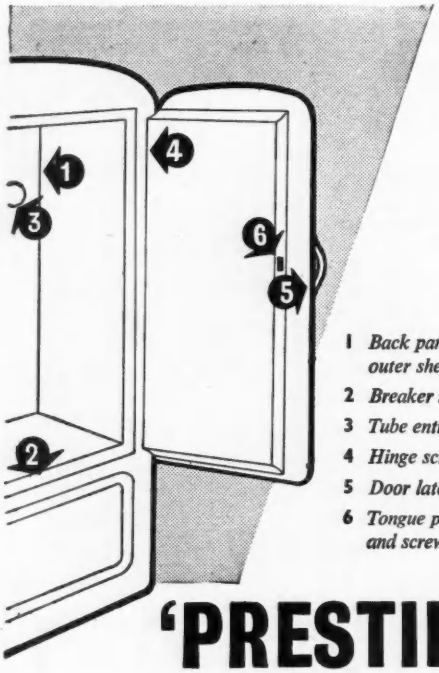


SPENCER & SONS (MARKET HARBOROUGH) LTD.

METAL FABRICATION FOR THE ELECTRONICS INDUSTRY

We are always pleased to advise on any specialised fabrication work without obligation.

GREAT BOWDEN ROAD · MARKET HARBOROUGH, E · LEICESTERSHIRE · PHONE: 2651/2



1 *Back panel outer shell*
2 *Breaker strip*
3 *Tube entry*
4 *Hinge screws*
5 *Door latch*
6 *Tongue plate and screws*

'PRESTIK'

SEALING STRIP

points to perfect sealing

A special grade of 'PRESTIK' has been developed for refrigerator sealing following 'PRESTIK'S' successful usage in many branches of the electrical industry, e.g. radio apparatus, washing machines and switchboxes.

'PRESTIK' provides an easy and efficient means of sealing against moisture; it is non-corrosive and withstands extremes of temperature.

'PRESTIK' and 'BOSTIK' together can provide the answers to your adhesive and sealing problems. Call the 'BOSTIK' man for advice on the manner in which 'PRESTIK' and 'BOSTIK' products can help you.

PRESTIK

SEALING STRIP

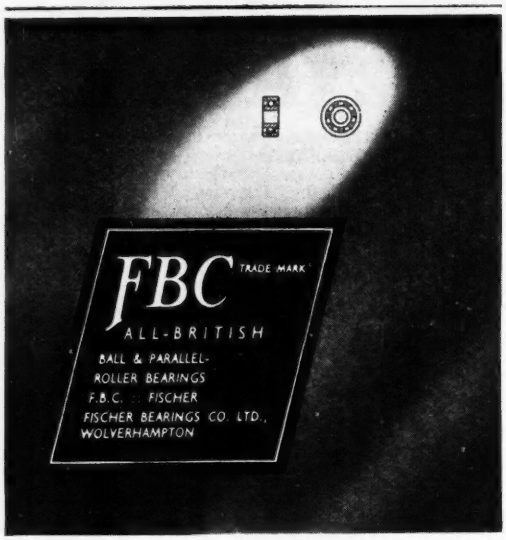
manufactured by the sole proprietors:

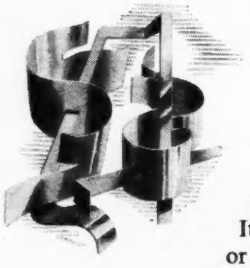
B. B. CHEMICAL CO. LTD

ULVERSCROFT ROAD, LEICESTER

Miniature bearings

TO ALL SIZES AND SPECIFICATIONS





NO TROUBLE AT ALL!

The shape of things to come. It may be eccentric or square and solid—it may be designed for beauty or utility—whatever you need, if it requires that we should shape metal to a particular need—to perform a certain function or stand a particular stress—then send us details and ask us to quote for. It's NO TROUBLE AT ALL.

RITHERDON
• & COMPANY LIMITED •

RITHERDON & CO. LTD.

Lorne Street, Darwen. Telephone: Darwen 1028

In six grades from soft to rock hard, and four qualities from medium grey to superfine, high-quality white, our range of polishing bobs includes the ideal wheel for every class of work. Send to-day for our free, illustrated brochure.

COOPERS FELT

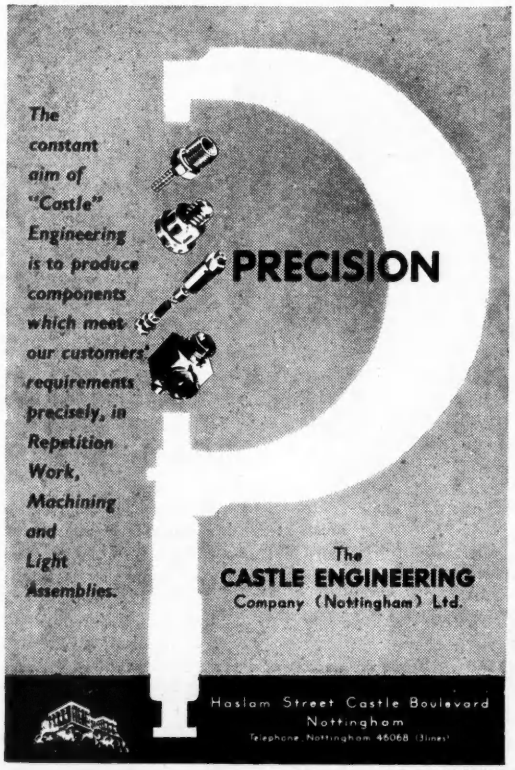
Please send all enquiries to Head Office and Works:

COOPER & CO. (B'ham) Ltd.

BRYNMAWR, BRECONSHIRE

Tel.: Brynmawr 312 *Telegrams: Felting Brynmawr*

Registered Office & Works: Little King Street, Birmingham, 19


The constant aim of "Castle" Engineering is to produce components which meet our customers' requirements precisely, in Repetition Work, Machining and Light Assemblies.
PRECISION
The
CASTLE ENGINEERING
Company (Nottingham) Ltd.
Haslam Street Castle Boulevard
Nottingham
Telephone Nottingham 46068 (3 lines)

L 4232 A

4 mmf/ft

AIR-SPACED ARTICULATED

CO-AX CABLES

offer a unique combination of

- ✔ FRACTIONAL CAPACITANCE
- ✔ HIGH IMPEDANCE
- ✔ MINIMUM ATTENUATION

ALONG WITH

- ✔ EXCEPTIONAL FLEXIBILITY
- ✔ LIGHT WEIGHT

38 STOCK TYPES

FOR ANY OF YOUR STANDARD OR SPECIAL APPLICATIONS

A few of the very low capacitance types are:

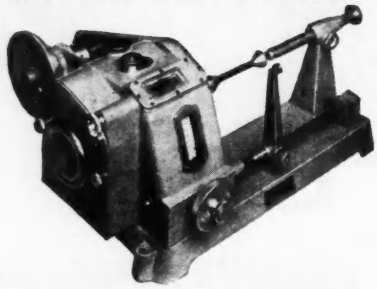
Type No.	*Capacit. μμ F/ft.*	*Impedance ohms*	*O.D.*
C.44	4.1	252	1.03"
C.4	4.6	229	1.03"
C.33	4.8	220	0.64"
C.3	5.4	197	0.64"
C.22	5.5	184	0.44"
C.2	6.3	171	0.44"
C.11	6.3	173	0.36"
C.1	7.3	150	0.36"

TRANSRADIO LTD.

CONTRACTORS TO H.M. GOVERNMENT

138A CROMWELL ROAD, LONDON, S.W.7

WELLINGTON **WAVE WINDING MACHINE**



Coils with diameters of $\frac{1}{4}$ in. up to 3 in. and with any width between $\frac{1}{8}$ in. and 1 in. may be wound either close or spaced, with a wave form of $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, 1, 2 or 3 waves per turn of coil.
Many refinements are embodied, previously obtainable only on elaborate machines.

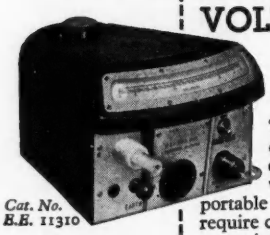
NEVILLE'S (LIVERPOOL) **LTD.**

A Subsidiary of Aeronautical & General Instruments Ltd.

PURLEY WAY, CROYDON, ENGLAND

Phone : Thornton Heath 3211 — *Cables :* Instradio, Croydon

SCALAMP ELECTROSTATIC VOLTMETER



Cat. No. B.E. 11310

DIRECT READING.

ZERO CURRENT DRAIN.

THREE SECONDS PERIOD.

LAMP OPERATES FROM MAINS OR 4 VOLT BATTERY.

BRIGHT SPOT-AND-HAIRLINE INDICATOR.

This instrument introduces a completely new conception of electrostatic voltmeter. It is compact, portable and robust, and does not require critical levelling or special mounting. The movement has a taut suspension, is critically damped, and readings can be taken with rapidity and ease. Three models are available:

Cat. No. E.E. 11308
1 - 5 kV A.C. D.C.
Cat. No. E.E. 11309
3 - 10 kV A.C. D.C.
Cat. No. E.E. 11310
5 - 18 kV D.C. and
5 - 12 kV A.C. R.M.S.

Please write for illustrated leaflet.

SCIENTIFIC PYE INSTRUMENTS

W. G. PYE & CO. LTD., GRANTA WORKS, CAMBRIDGE

What's behind all this

WEBB'S ORGANISATION

Geared to provide the professional user with complete apparatus or individual components from stock, and organised to give a "Same Day Service".

'Phone GERrard 2089

WEBB'S Radio

14, SOHO STREET, OXFORD STREET, LONDON, W.1.

Telephone : GERrard 2089. **SHOP HOURS : 9 a.m. - 5.30. p.m. SATS. 9 a.m. - 1 p.m.**

Excellence in design...

TYPE APPROVED CAT. A. NO. 464

AIR DIELECTRIC TRIMMER

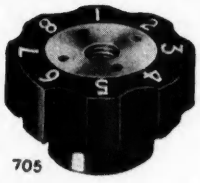
(Protected by Acetate Case)

Capacities from 4 to 70pF in voltages of 500 and 1000 D.C. Width 16.5 mm. Length 22 mm. Acetate dust cover optional. Insulation over 10,000 megohms. Power factor less than ·001

OXLEY

DEVELOPMENTS CO. LTD.

ULVERSTON, NORTH LANCS. · TEL.: ULVERSTON 3306



705

As manufacturers of Thermo Setting PLASTIC MOULDINGS, we specialise in the requirements of the Electrical and Radio trades for such items as control knobs, insulators and many other components. Our prices are competitive and delivery is prompt. May we quote you ?

Established 1928

HARRISON BROS

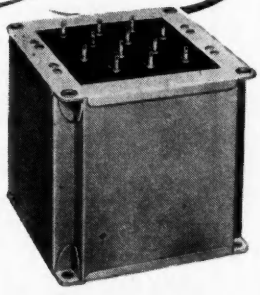
(PLASTICS) LIMITED

39-43, BRANSTON ST · BIRMINGHAM 18

Telephone: COLmore 4270

Telegrams: "ARISUN, Phone, Birmingham"

ABOVE ALL OTHERS



POTTED AND COMPOUND FILLED TRANSFORMERS AND CHOKES

made by Woden are the answer when the call is for transformers to operate under exacting industrial conditions, coupled with adverse climatic conditions.

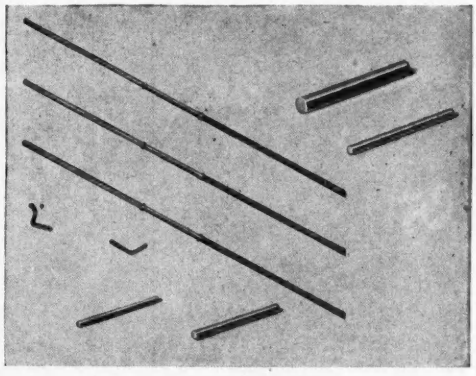
Every transformer leaving our factory is subjected to a rigid inspection, and is fully impregnated with moisture proof filling compound by the latest vacuum and pressure process. The fact that "WODEN" are the choice of many leading radio and television manufacturers is proof enough of the quality of our products.

Please send for latest Catalogue.

WODEN TRANSFORMER Co LTD

MOXLEY ROAD, BILSTON, STAFFS.

TELEPHONE: BILSTON 41959



TUNGSTEN RODS & THREE PIECE LEAD WIRES FOR TUNGSTEN TO GLASS SEALS

X-RAY TARGETS WITH OR WITHOUT CAST-ON COPPER BODY. ROTATING ANODES.

MOLYBDENUM TUBES & OTHER MOLYBDENUM COMPONENTS.

TUNGSTEN WELDING ELECTRODES FOR INERT GAS ARC WELDING. TUNGSTEN CONTACT RIVETS & SCREWS.

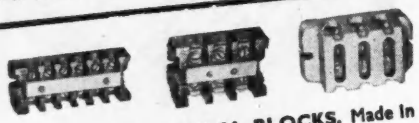
EA LIMITED

ELECTRO-ALLOYS Ltd.

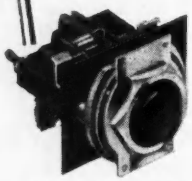
12, BRUNEL RD., LONDON, W.3.

Makers of TUNGSTEN *and* MOLYBDENUM *Products*

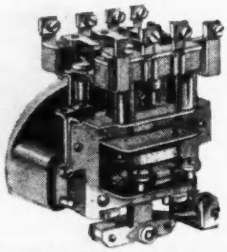
DONOVAN ACCESSORIES— FOR THE ELECTRONIC APPARATUS MANUFACTURER!



TYPE J.96 TERMINAL BLOCKS. Made in 15, 30 and 60 amp. sizes.



Type C.30 PUSH-BUTTON UNIT arranged for mounting on customers' own cover plate.



Type A.11 A.C. POWER RELAY – 4-pole with N.O. or N.C. contacts.

THE DONOVAN ELECTRICAL CO. LTD.
Safuse Works · Stechford · Birmingham 9

CLATONRITE
ANTI-VIBRO CLIP

EDGES ALSO RUBBER COVERED

THE extreme edges of this clip are rubber protected thus fully shrouding the clip, avoiding metal to metal contact and absorbing vibration. It is available either in full circular or saddle type, in nominal pipe diameters from ¼ in. to 2½ in., in flexible steel or aluminium. All types of this clip are offered either as a plain type or providing electrical contact through a metal tongue. Full literature is available on request.

Department A.O.
HOWARD CLAYTON-WRIGHT LIMITED
WELLESBOURNE WARWICKSHIRE
Phone: Wellesbourne 316/7/8 *Grams: Clatonrite Wellesbourne*

We specialize in
STABILIZED POWER SUPPLIES
covering all voltages from 1 volt — 75,000 volts.
From Stock :—
CAPACITY BOX. ·001 – ·999 mfd. Price £15.
Metal Rectifiers of all types.
London Stockists :— E.I.C. Meters.
Write for full specifications to :—
Henry A. Patterson & Partners Ltd.
ELECTRONIC LABORATORY FURNISHERS
156 High Holborn, LONDON, W.C.1.
Phone : CHAncery 7717
and at High Wycombe. *Phone : PENN 2334*

SPECIALISTS IN PACKING ELECTRONIC EQUIPMENT
SYNTHETIC SUPPLIES LTD.
ALBERT MILLS · SILK STREET
ECCLES · MANCHESTER
Telephones : ECCles 1720 & 3225/6

Casemakers and general joinery : Packing and Preservation : Shipping and Forwarding Agents: Warehousing

Contractors to the Admiralty, Air Ministry, Ministry of Supply & G.P.O. Approval No. B23789/40

WE TALK YOUR LANGUAGE
when it comes to TRANSFORMERS
★ designed for standard & special applications.
★ built for reliability.
★ engineered for trouble-free operation.

LAMALAC
INSULATION

SYNTHETIC RESIN LAMINATED MATERIALS

Sheet, Rod and Tube in all dimensions, Bobbins & Coil Formers to any specification

MICA AND MICANITE SHEET AND MANUFACTURED PARTS

MICA & MICANITE SUPPLIES LTD.,
BARNSBURY SQUARE, LONDON, N.1.
Phone: NORth 3032/5 Grams: MICASULIM, LONDON

L. WILKINSON WHOLESALE AND EXPORT
19, LANSDOWNE ROAD, CROYDON
Phone: CRO 0839 *Telegrams*: "WILCO" CROYDON

RELAYS—P.O. TYPE 3,000

BUILT TO YOUR SPECIFICATION—EARLY DELIVERY QUOTATION BY RETURN—PLEASE STATE RESISTANCE OF COIL REQUIRED AND CONTACT BUILD UP.

BREEZE SOCKETS. 6 Pole No 10H/408 Elbow type, 20,000 in stock, plugs to match available.

RACKS. Standard 6ft. P.O. type for 19in. panels, steel channel sides correctly drilled, heavy angle base.

WIRE WOUND RESISTORS. Green Vit 2,000 ohms, 75 watt. 5,000 in stock, also most other values.

POTENTIOMETERS. Wire wound and carbon, best makes, large stocks, low prices, list available.

RECTIFIERS METAL. Prompt delivery given for most types, send us details of your requirements.

JACKS. Short bakelite type P73. 1/6 each

KEY SWITCHES. P.O. type 212. 4000 available.

INSULATION

Our products include—
Presspahn and Leatheroid; Pressboard; Vulcanized Fibre; Cable and Red Rope Paper; Bakelite and Ebonite; Varnished Paper and Tapes; Varnished Silks and Tapes; Varnished Glass and Tapes; Varnished Cambric, Silk, Glass and P.V.C. Sleevings; Cotton Tapes, Webbings and Sleeving; Chattarton Compound; Adhesive and Rubber Tapes.

PRESSPAHN, LTD.
Bradford, Yorks, England
Established 1900

REGISTERED ELECTRICAL WELLSTEAD INSULATION TRADE MARK

Telephone: Bradford 25135 Pvt. Br. Ex.)
Telegrams & Cables: "Presspahn, Bradford"

POTENTIOMETERS

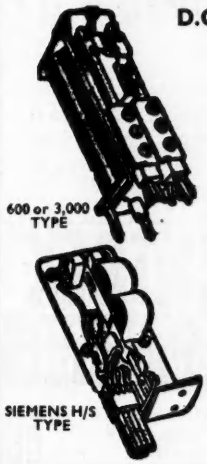
Wire-wound and Composition types. Single, Ganged, Tandem Units. Characteristics: linear, log., semi-log., non-inductive etc. Full details on request

RELIANCE
RELIANCE MNFG., CO. (SOUTHWARK), LTD.,
SUTHERLAND ROAD, HIGHAM HILL, WALTHAMSTOW, E.17.
Telephone: Larkswood 3245

A·D·S RELAYS Ltd
Late ALEC DAVIS SUPPLIES LTD.

Dept. E.E.
18 TOTTENHAM COURT ROAD, LONDON, W.1.
Tel.: MUSeum 2453/4539
Business Hours:
Monday - Friday 9—5.30
Saturday 9—1

RELAYS



D.C. COIL RESISTANCE

3,000 TYPES: 1.9Ω to 80,000Ω
600 TYPES: 0.4Ω to 9,200Ω.

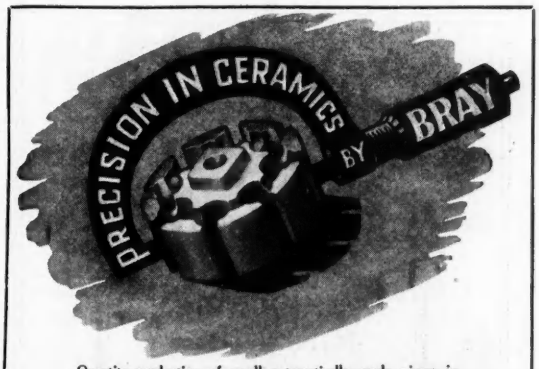
ALSO LARGE STOCKS OF DOUBLE & TRIPLEWOUND AND SLUGGED COILS.

CONTACTS

3,000 TYPES: up to 8 sets.
600 TYPES: up to 4 sets.
3,000 TYPES: Make (M), Break (B), in Twin - silver, Twin - platinum, Dome-silver (2 amp.), Tungsten (5 amp.), and Flat-silver (8 amp.). Change-over (C), in all but Tungsten; Make-Before-Break (K), in Twin-silver and Twin-platinum.

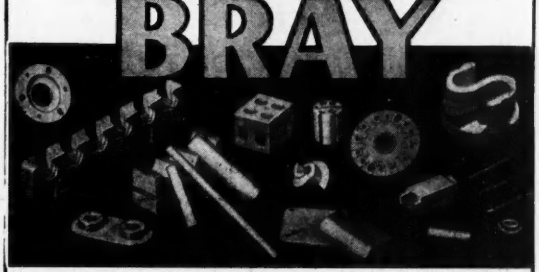
600 TYPES: (M), (B) and (C), in Twin-silver and Twin-platinum.

SPECIAL
High resistance slugged coils (up to 10,000 OHMS with 1" slug) now available.



Quantity production of small automatically made pieces in Steatite, Porcelain, and Rutile materials for electric cooking and heating equipment, and telecommunication apparatus.

BRAY



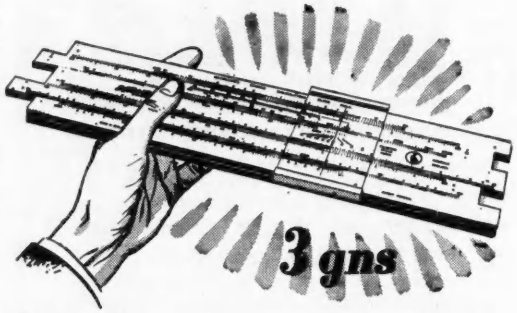
GEO. BRAY & CO. LTD., Leicester Place, Leeds 2.
Tel.: 20981/8. *Grams.*: "*Bray, Leeds 2*"

the answer to *your* problem?

'SINTREX' Electrolytic Iron Powder has solved many problems in electronics. Its exceptional purity gives it excellent electro-magnetic properties—ensuring high permeability and low losses in components such as small transformer cores, pole pieces, etc., for radio, T.V., fluorescent units, measuring instruments and much other equipment.

'SINTREX'
ELECTROLYTIC IRON POWDER

GEORGE COHEN SONS & CO. LTD
BROADWAY CHAMBERS · LONDON · W.6
Telephone: Riverside 4141
THE 600 GROUP OF COMPANIES
EE/533/IP3



Cut the stress and strain from spring calculation

WITH A 'RATCLIFFE'
SPRING CALCULATING SLIDE RULE

- ★ Scales allow all calculations involved in the design of helical tension and compression springs to be made *at one setting* !
- ★ Upper slide for stress and load calculations !
- ★ Wahl's stress correction calculated quickly !
- ★ The rule is essential to engineers and draughtsmen, is soundly constructed and supplied in a strong case complete with instructions.
- ★ Price **£3.3.0.** Send for one to-day.

J.S. Ratcliffe (ROCHDALE) LIMITED
CRAWFORD SPRING WORKS, ALLEN ST., ROCHDALE, LANCS.

HIVAC
THE SCIENTIFIC VALVE
BRITISH MADE

Pioneers and specialists in Small Valves

MIDGETS
MINIATURES
SUB-MINIATURES
ELECTROMETERS

★

COLD CATHODE TUBES

★

INDICATOR LAMPS
NEON INDICATOR LAMPS

Hivac Ltd
GREENHILL CRESCENT, HARROW-ON-THE-HILL, Middx.
Telephone: HARrow 2655

BRADMATIC LTD.

HIGH QUALITY TAPE RECORDING EQUIPMENT

THE MODEL 5D TAPE DESK (to take 10½in. NAB Reels)
Programme Time : 62 minutes at 7½ i.p.s.
124 minutes at 3¾ i.p.s.
Panel size : 20in. x 14½in.
Two speeds, 3¾ and 7½ i.p.s. Double track heads. Push button control. Fast wind and rewind. Three heavy duty motors. Three separately shielded heads. Complete with NAB reel adaptors
PRICE : (fitted with 6RP heads) **£50/-/-.**

ALSO AVAILABLE

MODEL 5C TAPE DESK (to take 9½in. reels).
Programme Time : 55 mins. at 7½ i.p.s.
110 mins. at 3¾ i.p.s.
PRICE : (fitted with 6RP heads)
Large Panel (20in. x 14½in.), **£47/10/-.**
Small Panel (13¾in. x 15½in.), **£45/10/-.**

MODEL 5B TAPE DESK (to take 7in. reels).
Programme Time : 31 mins. at 7½ i.p.s.
62 mins. at 3¾ i.p.s.
PRICE : (fitted with 6RP heads)
Panel size (13¾in. x 15½in.), **£42/-/-.**

PORTABLE RECORDERS

In rexine covered case, fitted with model 5B tape desk, type D.2. C.J.R. amplifier with monitoring. Provision for external loud-speaker.

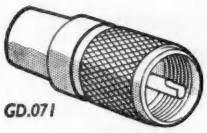
PRICE : £117/-/- (without microphone).

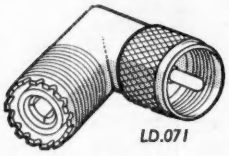
High fidelity sound heads. Type 5RP (Record/play), **£3/5/-.** Type 6RP (super fidelity), **£3/15/-.** Type 5E (Erase), **£3/5/-.** Mumetal Screening cans, 8/6. Amplifiers, microphones. All types and sizes of magnetic tape.

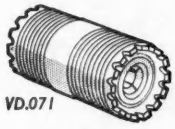
Trade supplied. *Send for Lists.*

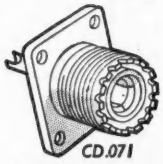
BRADMATIC LIMITED
STATION ROAD · ASTON · BIRMINGHAM 6
Phone : EAST 0574 *Grams : Bradmatic, Birmingham*

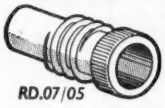
SCREENED CONNECTORS


GD.071


LD.071


VD.071


CD.071


RD.07/05

for cables of 0.2″ to 1.03″ O.D.
Single and multi-way types.
Special types fitted with coupling rings.
Cable joining connectors.
U.S. Type Connectors as illustrated.

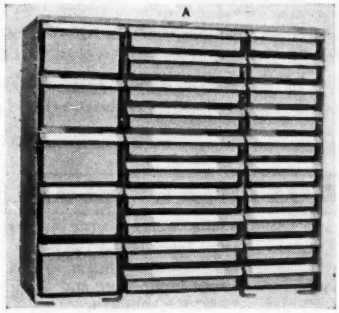
CABLE O.D.	TYPE	CODE NO.
0.41″	Straight plug	GD.071
0.25″	Reducing adaptor	RD.07/05
0.2″	Reducing adaptor	RD.07/03
fits on GD.071 CD.071 VD.071	Elbow plug adaptor	LD.071
fits on GD.071 LD.071	Bulkhead (Junction) adaptor	VD.071
fits on GD.071 LD.071	Chassis receptacle	CD.071

Other Transradio specialised products:
CO-AX air-spaced articulated
Very Low Loss Cables.
Microdual Two-speed Precision Drives.

TRANSRADIO LTD
138A CROMWELL ROAD, LONDON, SW7, ENGLAND
Telephone: FREmantle 4421 (P.B.X.)

TRAY STORAGE FOR THE INDUSTRY

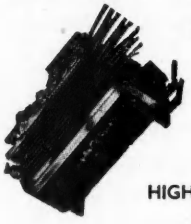
Self build tray Storage units from only five basic components. Three sizes of trays available. Units erected in minutes.



Write for details of RECEPTORAK and other RANDALL PRODUCTS or when in town call at Showrooms.

RANDALRAK LTD.,
(Dept. E.E.) 106 VICTORIA STREET, LONDON, S.W.1.
Telephone : VICtoria 3485-4238

MAGNETIC RELAYS



Built to your Specification

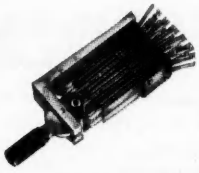
TYPES 3000 and 600
HIGH SPEED and A.C. to 400 VOLTS

UNISELECTOR **SWITCHES**

From 3 to 8 Bank — All Resistances

KEY SWITCHES

Several types in stock

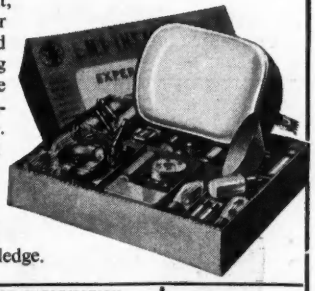


JACK DAVIS (RELAYS) LTD.
36 PERCY STREET · LONDON · W.1
MUSEUM 7960 LANGHAM 4821

NEW! RADIO, TELEVISION AND ELECTRONICS LEARN THE PRACTICAL WAY

Instruction *and* Equipment

Here at last is the only *real* way of making home study really successful. Specially prepared equipment, which remains your property, is supplied thus combining theory and practice in the correct educational sequence. Whether your need be for career, hobby or general interest, here is a most efficient method for acquiring knowledge.



POST NOW FOR FREE INFORMATION

To: E.M.I. INSTITUTES, Dept. 11x, Grove Park Rd., Chiswick, London, W.4.

NAME.....

ADDRESS.....

.....

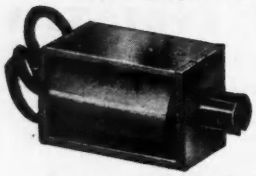
IC208

E.M.I. INSTITUTES

The only Postal College which is part of a world-wide Industrial Organisation.

PHIL-TROL SOLENOIDS

6 v. — 460 v., A.C. and D.C. versions



Now made in England.

The first of this very popular range of solenoids or actuators is the small types 41 & 42. Now in Production.

Samples now available of the larger types 38 and 39.

WRITE FOR PAMPHLETS AND DETAILS:—

PHILLIPS CONTROL (G.B.) LTD.

273 Farnborough Road, Farnborough, HANTS.

Telephone : Farnborough 1120

INDUSTRIAL PROBLEMS

No. 4. SOUND LEVEL METER & VIBRATION METER.
(Dawe. Types 1400 & 1402)

Motor Engineers. Electrical Engineers. All Machinery Manufacturers. Audio Equipment and Studio design Manufacturers. Aircraft Manufacturers.
Your Noise and Vibration problems can be solved by these two instruments. Will measure anything, anytime and anywhere. Completely portable.
Sound Level Meter range. 30 d b.—126 d b.
Vibration Meter Range (1) Vibration .00002" to 30".
(2) Velocity of Vibration 0.0002" to 300" per second.
(3) Acceleration of Vibration 0.2" to 2,700" per second.

For QUICK Service consult :—

A. C. FARNELL LTD., 15 Park Place, Leeds, 1.

Telephone : Leeds 32958/9.

(Official Agents for Advance, Avo, Cossor, Dawe and Waveforms.)

TRANSFORMERS
CHOKES
SOLENOIDS
COILS

- MADE TO YOUR SPECIFICATION IN ANY QUANTITY AT COMPETITIVE PRICES
- HIGHEST GRADE MATERIALS AND INSULATIONS USED
- DIE CAST FRAMES OR MOUNTING BRACKETS MADE FOR ALL FITTINGS

Send your enquiries to :-

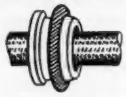
W.L.R.S. LTD.

DELTA HOUSE, 30 FAUCONBERG RD., CHISWICK, W.4

CHIS. 0384

High-class equipment needs the best components

Such as these



The Insuloid "RING-LOCK" Cable Bush

The Insuloid "PLASKLIP" Cable Clip

APPROVED FOR SERVICE USE

INSULOID MANUFACTURING Co. Ltd.

SHARSTON WORKS, LEESTONE AVENUE
WYTHENSHAWE, MANCHESTER
Tel. : Wythenshawe 2842

P.3

FIRE !

PRODUCTION LOST BUT FOR

NU-SWIFT !

A spark...a flash...fire blazing...dial 999 ! But for at least five minutes that blaze will be YOURS alone! Reliable Nu-Swift is the world's fastest and most certain fire-killer.

NU-SWIFT LTD · ELLAND · YORKS

In Every Ship of the Royal Navy

SERVOTRONIC SALES invite enquiries

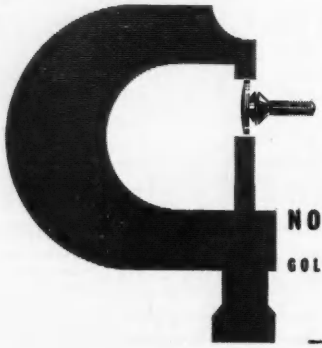
for the following specialised items of Electro-Mechanical and Electronic equipment :—

MAGSLIPS and accessories — SELSYNS
IPOTS — SINE-COSINE POTENTIOMETERS
VELODYNES and A.C. SERVO MOTORS
VARIABLE FREQUENCY SINE-WAVE GENERATORS
PRECISION GEARS — REPEATER MOTORS

Technical Data, Prices and Deliveries from:—

SERVOTRONIC SALES INC. HOPTON RADIO
No. 1, Hopton Parade, Streatham High Road
London, S.W.16 Tel. : Streatham 6165

bona fide enquiries only please



CONSISTENT ACCURACY. . .

. . . in precision auto-turned parts

Trouble-free assembly is guaranteed by first-class workmanship and modern plant. Quantity production of parts turned to your own specification, up to a maximum diameter of 1¼ in. A.R.B. Approved.

NORTHERN AUTOMATIC SCREW CO. LTD.

GOLF ROAD · HALE · ALTRINCHAM · CHES · PHONE · ALT · 2184 · 2497

DEVELOPMENT ENGINEERS, SENIOR AND JUNIOR

Senior Engineers with initiative and sound technical background are required for work on a wide range of projects covering the Television, Radio and Communications field. Permanent posts are available for men able to carry responsibility in rapidly expanding departments offering exceptional promotion and long term prospects.

Junior Engineers of ability are invited to apply for interesting work on Development Projects offering a wide experience in Communications and Test Equipment Development with excellent prospects for advancement.

The Laboratories are well equipped and the working conditions excellent. Successful applicants will be eligible for the Company's Pension Scheme. Housing assistance considered. Applications giving full particulars as to age, qualifications and experience etc. in writing, to:

Employment Manager

FERGUSON RADIO CORPORATION LTD.

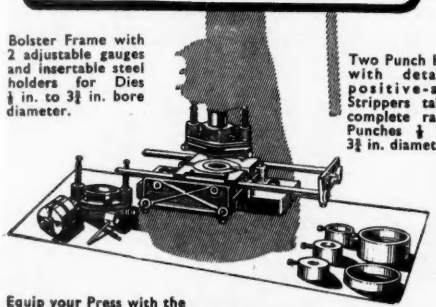
GREAT CAMBRIDGE ROAD., ENFIELD, MIDDLESEX

REDUCE YOUR PRESS TOOL COSTS

THE HUNTON UNIVERSAL BOLSTER OUTFIT FOR SHEET METAL PIERCING AND BLANKING ON FLY PRESSES

Bolster Frame with 2 adjustable gauges and insertable steel holders for Dies ¼ in. to 3¾ in. bore diameter.

Two Punch Holders with detachable positive-action Strippers take the complete range of Punches ¼ in. to 3¾ in. diameter.



Equip your Press with the Hunton Outfit and use **inexpensive standardised Punches and Dies ¼ in. to 3¾ in. diameter obtainable from stock—in $\frac{1}{32}$ in. sizes**—when you need them. Standardised Tools also available at short notice for Square, Oblong and other shapes, Louvre Forming (up to 8 in. long), Corner Notching, Corner Radiusing, Angle Iron Notching and Piercing, etc.

Get the outfit now—Buy Punches, Dies and tools as you need them

Descriptive brochure and prices on request.

HUNTON LIMITED

Phoenix Works, 114-116, Euston Road, London, N.W1.

Telephone: Euston 1477 *Telegrams:* Untonexh, London

"SPEARETTE"

MINIATURE VALVE WIRING JIGS

TYPES NOW AVAILABLE INCLUDE B3G, B7G, B8A, B8G, B9A AND B9G.

SPEAR ENGINEERING CO. LTD.

TITAN WORKS, WARLINGHAM, SURREY.

Telephone: Upper Warlingham 2774.

'Radiospares' Quality Parts

The Service Engineer's First Choice

MECHANICAL DESIGNER

VIDOR/BURNDEPT offers senior position on Electronic Laboratory staff with responsibility for original design on prototype work of national importance. Extremely good salary and prospects await successful candidate, who should have wide experience in miniaturisation techniques, plastics, mouldings and allied trades.

Write with full particulars to Personnel Manager, West Street, Erith, Kent.

INDEX TO ADVERTISERS

A.B. Metal Products Ltd. 42
Adam Bros. & Burnley Ltd. 61
A.D.S. Relays Ltd. 75
Aero Research Ltd. 25
Air Control Installations Ltd. 14
Airmec Ltd. 50
All-Power Transformers Ltd. 56
Amos of Exeter 74
Autoset (Production) Ltd. 68

Baldwin Instrument Co., Ltd. 62
B.B. Chemical Co. 70
Belling & Lee Ltd. 33
Bradmatic Ltd. 76
Bray & Co., Ltd., George 75
British Electric Resistance Co., Ltd. .. 64
British Insulated Callender's Cables Ltd. Cover i
British Iron & Steel Federation .. 26
British Physical Laboratories Ltd. .. 65
British Thomson-Houston Co., Ltd. .. 9
Burndept Ltd. .. .. .. 66 and 79

Castle Engineering Co. (Nottingham) Ltd., The 71
Chapman & Hall Ltd. 353
Cinema-Television Ltd. 18
Clayton-Wright Ltd., Howard 74
Cohen, Sons & Co., Ltd., George .. 76
Connolly's (Blackley) Ltd. 16
Cooper & Co. (Birmingham) Ltd. .. 71

Darwins Ltd. 65
Davis (Relays) Ltd., Jack 77
Dawe Instruments Ltd. 60
Donovan Electrical Co., Ltd. 74

Edison Swan Electric Co., Ltd., The Cover ii, 24 and 55
Edwards & Co. (London) Ltd., W. .. 69
Electro-Alloys Ltd. 73
Electro-Methods Ltd. 63
Electronic Engineering Monographs .. 353
E.M.I. Institutes Ltd. 77
English Electric Co., Ltd., The 15
Enthoven & Sons Ltd., H. J. 30
Erie Resistor Ltd. .. .. Cover iii

Farnell Ltd., A. C. 78
Ferguson Radio Corporation Ltd. .. 79
Ferranti Ltd. 23
Fielden (Electronics) Ltd. 12
Fischer Bearings Co., Ltd. 70

General Electric Co., Ltd., The .. 29
General Engineering Co. (Radcliffe) Ltd. 10
Goodman's Industries Ltd. 57
Graham Gear Co., Ltd. 74
Griffiths, Gilbart, Lloyd & Co., Ltd. .. 57
Guest, Keen & Nettlefolds (Midlands) Ltd. 62

Hairlok Co., Ltd., The 22
Harrison Bros. (Plastics), Ltd. 73
Hivac Ltd. 76
Hunton Ltd. 79

Insuloid Manufacturing Co., Ltd. .. 78
Isotope Developments Ltd. 59

Johnson, Matthey & Co., Ltd. 41

Kelvin & Hughes Ltd. 56

Labgear (Cambridge) Ltd. 3
Langham Thompson Ltd., J. 67
Leland Instruments Ltd. .. .. Cover iv
Linread Ltd. 13
Londex Ltd. 68
Lyons Ltd., Claude 20

Magnetic & Electrical Alloys Ltd. .. 54
Marconi Instruments Ltd. 43
Marconi's Wireless Telegraph Co., Ltd. 38
Measuring Instruments (Pullin) Ltd. .. 3
Metropolitan-Vickers Electrical Co., Ltd. 19
Mica & Micanite Supplies Ltd. 75
Micanite & Insulators Ltd. 44
Miltoid Ltd. 68
Minnesota Mining & Manufacturing Co., Ltd. 67
Mond Nickel Co., Ltd. 34
Muirhead & Co., Ltd. 47
Mullard Ltd. .. .. 31, 40 and 48
Murex Ltd. 80

Nagard Ltd. 45
Nash & Thompson Ltd. 61
Neville's (Liverpool) Ltd. 72
Northern Automatic Screw Co., Ltd. .. 78
N.S.F. Ltd. 51
Nu-Swift Ltd. 78

Oxley Developments Ltd. 73

Painton & Co., Ltd. 52
Parmeko Ltd. 5
Partridge Transformers Ltd. 8
Patterson & Partners Ltd., Henry A. .. 74
Phillips Control (G.B.) Ltd. 78
Presspahn Ltd. 75
Pye Telecommunications Ltd. 27
Pye & Co., Ltd., W. G. 72

Radiochemical Centre, The 21
Radiospares Ltd. 79
Ragosine Oil Co., Ltd. 58
Randalrak Ltd. 77
Ratcliffe (Rochdale) Ltd., F. S. 76
Reliance Manufacturing (Southwark) Ltd. 75
Ritherdon & Co., Ltd. 70

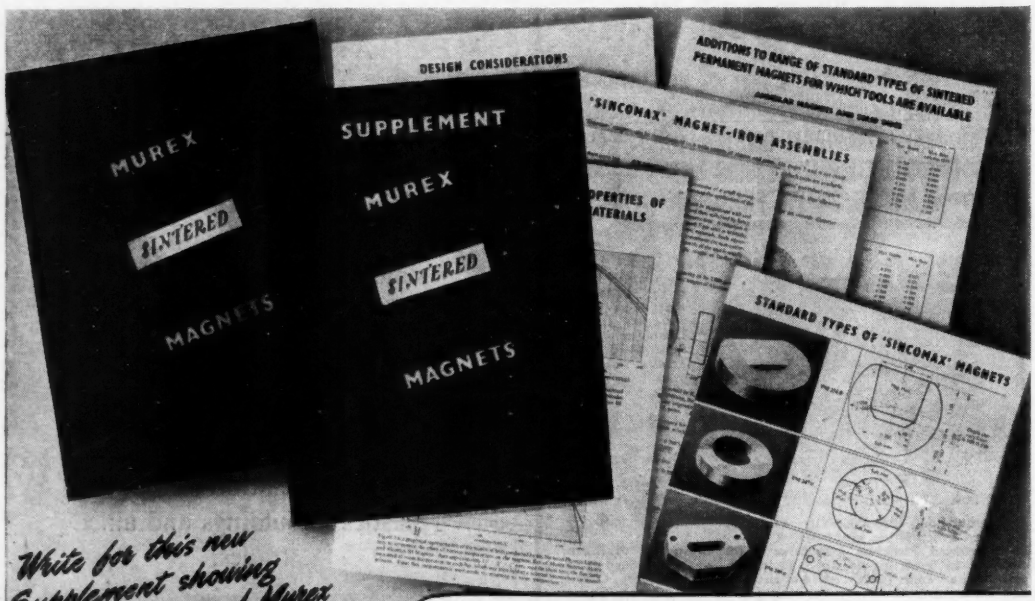
Salford Electrical Instruments Ltd. .. 46
Saunders-Roe Ltd. 11
Scott & Co., Ltd., A. C. 45
Servomex Controls Ltd. 49
Servotronic Sales 78
Sheffield Smelting Co., Ltd. 64
Solartron Laboratory Instruments Ltd. .. 7
Southern Instruments Ltd. 63
Spear Engineering Co., Ltd. 79
Spencer & Sons (Market Harboro') Ltd. 69
Standard Telephones & Cables Ltd. 32, 53 and 66
Sunvic Controls Ltd. 36
Synthetic Supplies Ltd. 74

Taylor Tunnicliff (Refractories) Ltd. .. 28
Telegraph Construction & Maintenance Co., Ltd., The 60
Transradio Ltd. .. .. 71 and 77
Truvox Ltd. 58
Twentieth Century Electronics Ltd. .. 35

Unbrako Socket Screw Co., Ltd. .. 37

Venner Accumulators Ltd. 39

Wayne-Kerr Laboratories Ltd. 17
Webb's Radio 72
West London Rewind Service Ltd. .. 78
Wiggin & Co., Ltd., Henry 8
Wilkinson, L. 75
Woden Transformer Co., Ltd. 73
Wright, Bindley & Gell Ltd. 59



Write for this new Supplement showing the latest range of Murex Sintered Permanent Magnets

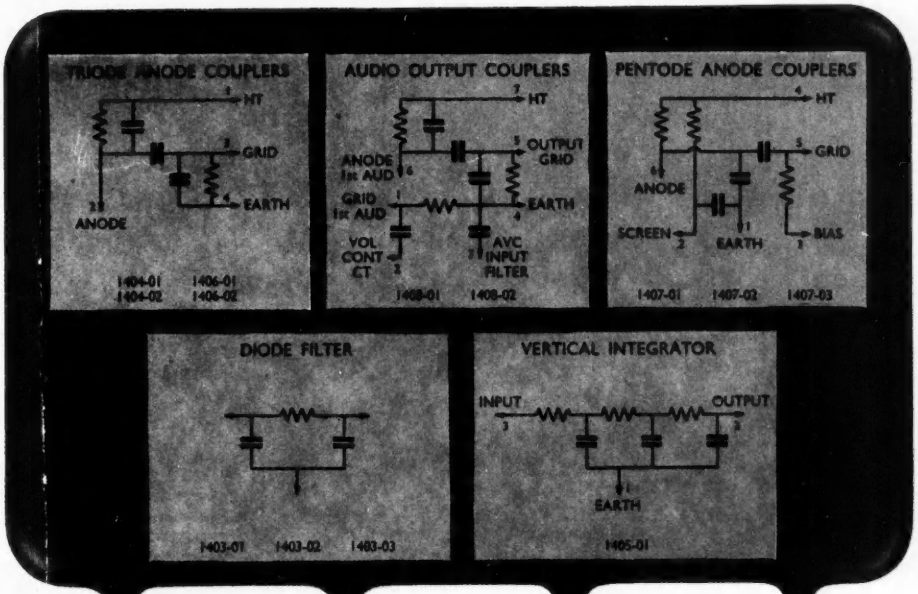
MUREX LIMITED *(Powder Metallurgy Division),*
RAINHAM, ESSEX. *Telephone : Rainham, Essex 3322.*

London Sales Office : CENTRAL HOUSE, UPPER WOBURN PLACE, W.C.1. Telephone : EUSton 8265

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers), Ltd., 28, Essex Street, Strand, W.C.2. Registered for Transmission by Canadian Magazine Post.

XU

ERIE* printed circuits



ERIE PRINTED CIRCUITS
offer these advantages

- Fewer soldered joints
- Fewer wiring errors
- Uniformity in layout
- Uniformity in quality
- Reduction in size and weight
- Reduction in cost of assembly
- Reduction in cost of handling

* *Registered Trade Mark*

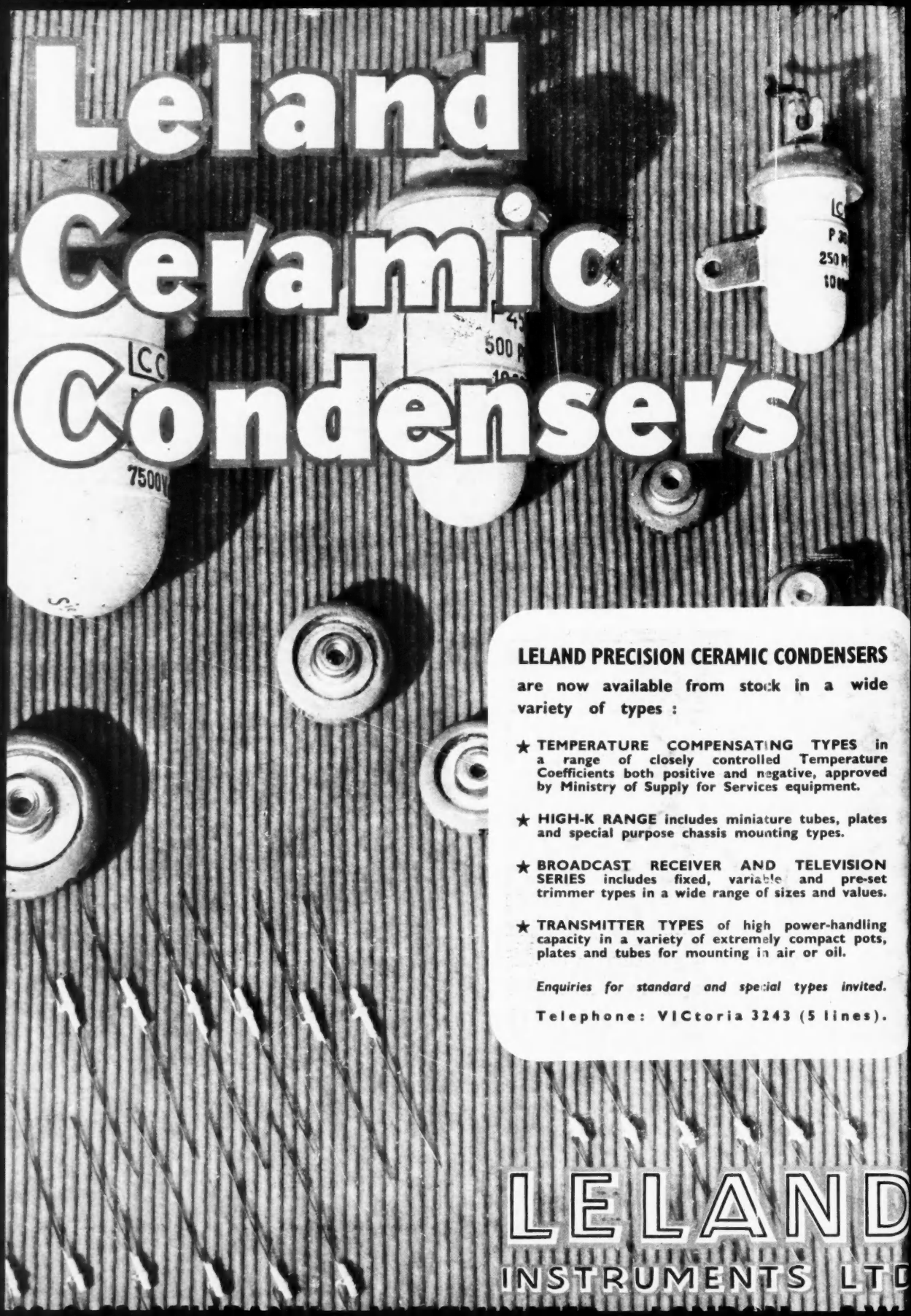
ERIE electronic printed circuits achieve miniaturisation by bonding a complete or partial circuit to a ceramic base plate, thus reducing a miscellany of resistors and capacitors to a single compact fully insulated unit.

Erie electronic printed circuits, first developed in 1940, having stood the test of time in world markets, are now available in this country

ERIE* Resistor Ltd

Carlisle Road, The Hyde, London, N.W.9, England. Telephone: COLindale 8011

Factories: London and Great Yarmouth, England; Toronto, Canada; Erie, Pa., U.S.A.


Leland
Ceramic
Condensers
LELAND PRECISION CERAMIC CONDENSERS
are now available from stock in a wide variety of types :
★ TEMPERATURE COMPENSATING TYPES in a range of closely controlled Temperature Coefficients both positive and negative, approved by Ministry of Supply for Services equipment.
★ HIGH-K RANGE includes miniature tubes, plates and special purpose chassis mounting types.
★ BROADCAST RECEIVER AND TELEVISION SERIES includes fixed, variable and pre-set trimmer types in a wide range of sizes and values.
★ TRANSMITTER TYPES of high power-handling capacity in a variety of extremely compact pots, plates and tubes for mounting in air or oil.
Enquiries for standard and special types invited.
Telephone: VICtoria 3243 (5 lines).
LELAND
INSTRUMENTS LTD